SCIENCE
IN MODERN LIFE

10 11

RACES OF MANKIND I

RACES OF MANKIND—I

1, Zulu (Bantu).
2, Pygmy (Negrillo).
3, Arab (Semite).
4, Bushman.
5, Touareg (Western Hamite).
6, Nubian.
7, Somali (Ethiopian).
8, Australian.
9, Maori (Polynesian).
10, Papuan (Melanesian).
11, Solomon Islander (Melanesian).

SCIENCE
IN MODERN LIFE

A SURVEY OF SCIENTIFIC DEVELOPMENT DISCOVERY AND INVENTION AND THEIR RELATIONS TO HUMAN PROGRESS AND INDUSTRY

PREPARED UNDER THE EDITORSHIP OF

J. R. AINSWORTH DAVIS

M.A. (Trin. Coll., Cambridge), F.C.P.

Author of "The Natural History of Animals" &c. &c.

WITH THE CO-OPERATION OF

A. C. D. CROMMELIN, B.A., F.R.A.S., of the Royal Observatory, Greenwich.

O. T. JONES, M.A., F.G.S., of H.M. Geological Survey.

J. P. MILLINGTON, M.A., B.Sc., formerly Scholar of Christ's College, Cambridge.

J. H. SHAXBY, B.Sc., Lecturer in Physics in University College, Cardiff.

H. J. FLEURE, D.Sc., Lecturer in Geology and Geography in University College, Aberystwyth.

H. SPENCER HARRISON, D.Sc., formerly Lecturer in Zoology in University College, Cardiff.

J. M. F. DRUMMOND, B.A., F.L.S., Assistant and Lecturer in Botany, University of Glasgow.

J. TRAVIS JENKINS, D.Sc., Ph.D., Scientific Superintendent of the Lancashire and Western Sea-Fisheries Committee.

JAMES WILSON, M.A., B.Sc., Professor of Agriculture in the Royal College of Science, Dublin.

BENJAMIN MOORE, M.A., D.Sc., Professor of Bio-Chemistry in the University of Liverpool.

J. W. FRENCH, B.Sc., Editor of "Modern Power-Generators", &c.

J. BEARD, D.Sc., Lecturer in Comparative Embryology, University of Edinburgh.

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Professor of Agriculture in the Royal College of Science, Dublin

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AGRICULTURE

BY

JAMES WILSON, M.A., B.Sc.
Professor of Agriculture in the Royal College of Science, Dublin

AGRICULTURE

CHAPTER I

BRITISH AGRICULTURE DURING SAXON TIMES AND UNDER THE FEUDAL SYSTEM

If we would predict what a nation may do in the future we must know not only what it is doing to-day but what it has done in the past. Similarly with agriculture: if we would know what may yet be drawn from the land, we must know not only what is being drawn from it to-day but what was drawn from it in times gone by. We must know not only the present state of agriculture but the steps by which that state has been reached. For this purpose British agriculture may be studied with profit. Its history is known, it has been the nursery of discovery and advance, and it is still the most efficient in the world.

CÆSAR'S ACCOUNTS.—The farmers of Britain are of two races, Germanic and Celtic[1], but their system of agriculture has been developed from that brought over by the Anglo-Saxons from Germany more than a thousand years ago. Of the individual tribes that came to Britain we have no specific knowledge, but Caesar tells us that in his day the Germans were engaged in agriculture and in hunting and warlike pursuits. They were clothed in skins, and lived upon milk, cheese, and flesh, with a little corn. Land was owned by the tribe as a whole, but was allotted annually for cultivation by individual members. A tribe did not remain more than a year in one place, lest the people should settle down in comfort and deteriorate in warfare. Carts and wagons were drawn by miserable, ill-shapen cattle. Horses were used in warfare, and some of the tribes near the Rhine owned boats and ships large enough to transport themselves and their horses.

DESCRIPTION GIVEN BY TACITUS.—About 150 years after Cæsar saw them the Germans were described again, this time by Tacitus. In the interval, without becoming less warlike, they have advanced in agriculture. Sheep are now mentioned as part of the live stock, and the men wear cloaks as well as skins. For the women's garments linen is used, from which we infer the growth and manufacture of flax. A liquor is fermented from barley or other grain. The people live in settled villages,

[1] "Celtic" refers to the races that were in Britain before the coming of the Romans.

each in the midst of a stretch of land proportionate in area to the number of its inhabitants. Each man's house, surrounded by a small open space, stands apart by itself. It is built of wood. To every free man, according to his rank, a portion of the arable land near the village is annually allotted for cultivation, no man receiving the same portion twice in succession. More grain is grown, and subterranean caves are dug, as well for its protection as for dwellings. Tacitus notes also a social change in which might be discerned the germ of Feudalism. Inequality is not yet great, but it is there. The people themselves might look upon it only as division of labour. Warlike young men flock to the side of some noted leader, who, for his services, is recompensed with stock and grain gifted by his own people or seized from other tribes. The leader in turn distributes these among his men who prefer living in this way to tilling the land.

For many years the Anglo-Saxons as farmers are obscured by their doings as conquerors and colonists. History takes much heed of military but little of agricultural affairs. But knowing something of their agriculture when Tacitus left it in darkness, and more when it emerged again into daylight, we may reconstruct the middle from the two ends.

LIFE OF THE CELTS.—But first we must realize that the Celts and the Romans had little influence upon British agriculture. Long after the Romans or even the Anglo-Saxons came to Britain the Celts were still semi-nomadic. They grew only a small quantity of grain, and that in a new place every year. Their food and clothing were obtained chiefly from small black cattle and brown or dun-faced sheep.

ROMANS.—The Romans came as conquerors, as expanders of their own civilization and trade, but not as farmers. They organized the country. They built fortresses and towns, with roads to connect them. They cultivated land on the Roman system near the Roman settlements. It is probable they introduced beans and peas, and, possibly, wheat. Like Europeans to-day, they introduced a new breed of cattle which became feral, *i.e.* ran wild, on their departure. Late in the feudal period twenty or more herds of these cattle—white cattle with black points—were enclosed in parks, some half-dozen of which still exist in England and Scotland. But Roman civilization was swept out by the incoming Anglo-Saxons; and the Celts, with the few remaining Romans, retired into the West. So completely was the country abandoned by the one race and colonized by the other that the cattle which the Anglo-Saxons brought over—the red cattle of the south of England—kept possession of the south and east of England down even to about the beginning of the eighteenth century.

VILLAGES.—In Britain the Anglo-Saxons settled down in villages of which those described by Tacitus were the germ, modified now, however, by advancing civilization and the discovery of several new crops through contact with Roman civilization either before or after leaving Germany. In Germany the tillage land usually grew grain for one year only, and was ploughed or fallowed the next; but in England, while some villages cultivated their land in this way, the vast majority came to take two crops of grain before laying the land fallow. Those crops were usually wheat,

but sometimes barley or oats, the first year, and beans, peas, barley, or oats the second.[1]

THE VILLAGE AND ITS LAND.—The territory of a village extended round it in all directions, and varied in extent with the number of its inhabitants. The village itself stood near the centre. Appropriate land near the village was selected for tillage. From other land suitable for the purpose hay was taken every year, and parts were set aside for grazing bullocks, cows, young stock, and sheep—those for cows and bullocks being as near the village as possible. The forest on the outskirts of all afforded food and shelter for swine, and supplied the villagers with firewood and timber. Every farmer had the right to certain areas of tillage and meadow land, and to grazing for definite numbers of each kind of stock. By a reasonable computation, based upon statements in Seebohm and Maitland as to the custom in Norman times, the Anglo-Saxon farmer of 15 acres of arable land must have held the right to graze a bullock, a cow, a young bullock or heifer, three or four sheep, and a similar number of pigs.

Fig. 385.—Ploughing

TILLAGE AREA.—The most important part of the village land was that under tillage. It was divided into three great fields, each of which was subdivided again into plots called "lands" or "furlongs", normally $5\frac{1}{2}$ yd. broad and 220 long, that is, a quarter of an acre. Every free man, according to his rank, in which there was but little difference, had a right to a certain number of acres of arable land, namely, to a third of that number in each of the three fields; and, so that he might neither suffer nor gain through the inequality of the land, his share was scattered about each field in separate acres or half-acres or even furlongs. For the same reason the tillage land was re-allotted periodically. Each farmer's plots being intermingled with those of his neighbours, it was necessary that all should grow the same kind of crop in the same field in the same year. Thus in any one year one of these three great fields was in wheat and other grain and was called the "wheat" field; another was in beans or peas and other grain and was called the "bean" or "pea" field; while the third was fallow.

TILLAGE.—The tillage land monopolized the bulk of the labour. During the fallow year it was ploughed four times at least:[2] first in April to lay up the turf and kill the weeds accumulated since last fallow; next

[1] Very little wheat and beans were grown north of the Humber.

[2] The three chief ploughings were called the een fallow, the twy fallow, and the try fallow in some parts of England so late as the eighteenth century.

in June, this time deeply, with the dung ploughed down; and again in July or August, once, or oftener if the weeds required it. After each ploughing the sods were torn up and the clods broken by mattocks and mallets. In autumn the "wheat" seed was sown and ploughed in. Next autumn, when the "wheat" crop was removed, the sheep were allowed on the stubble to glean and graze it, in consequence of which it was not ploughed till early the following spring. Shortly after the land was ploughed the "bean" crop was sown and ploughed in. The stubble of this crop was grazed similarly to that of the other crop.[1]

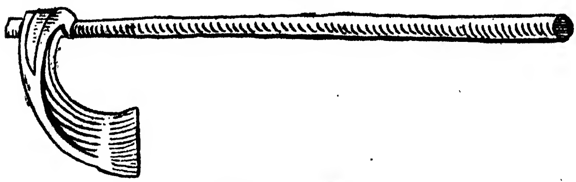


Fig. 386.—A Mattock

VARIED NATURE OF FARM WORK.—But the farmer and his sons had much other work to do: sowing, reaping, carrying and stacking, threshing by flail, and winnowing by the wind; hedging and ditching, cleaning out watercourses; turning and re-turning the dung heap; cutting and carrying timber and firewood; making and repairing roads; malting and brewing; attending and feeding cattle and other stock; making and mending harness and tools; building, thatching, and repairing houses; digging the garden or "yard"; steeping, scutching, and preparing flax or hemp, and so on; while the women looked after the housework, butter and cheese making, spinning, and making clothes.

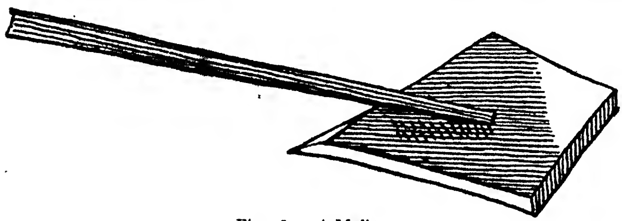


Fig. 387.—A Mallet

Fig. 388.—The Flail

[1] The "wheat" crop, being sown in autumn, was usually called the "autumn" or "winter corn"; the "bean" or "pea" crop was usually called the "spring corn".

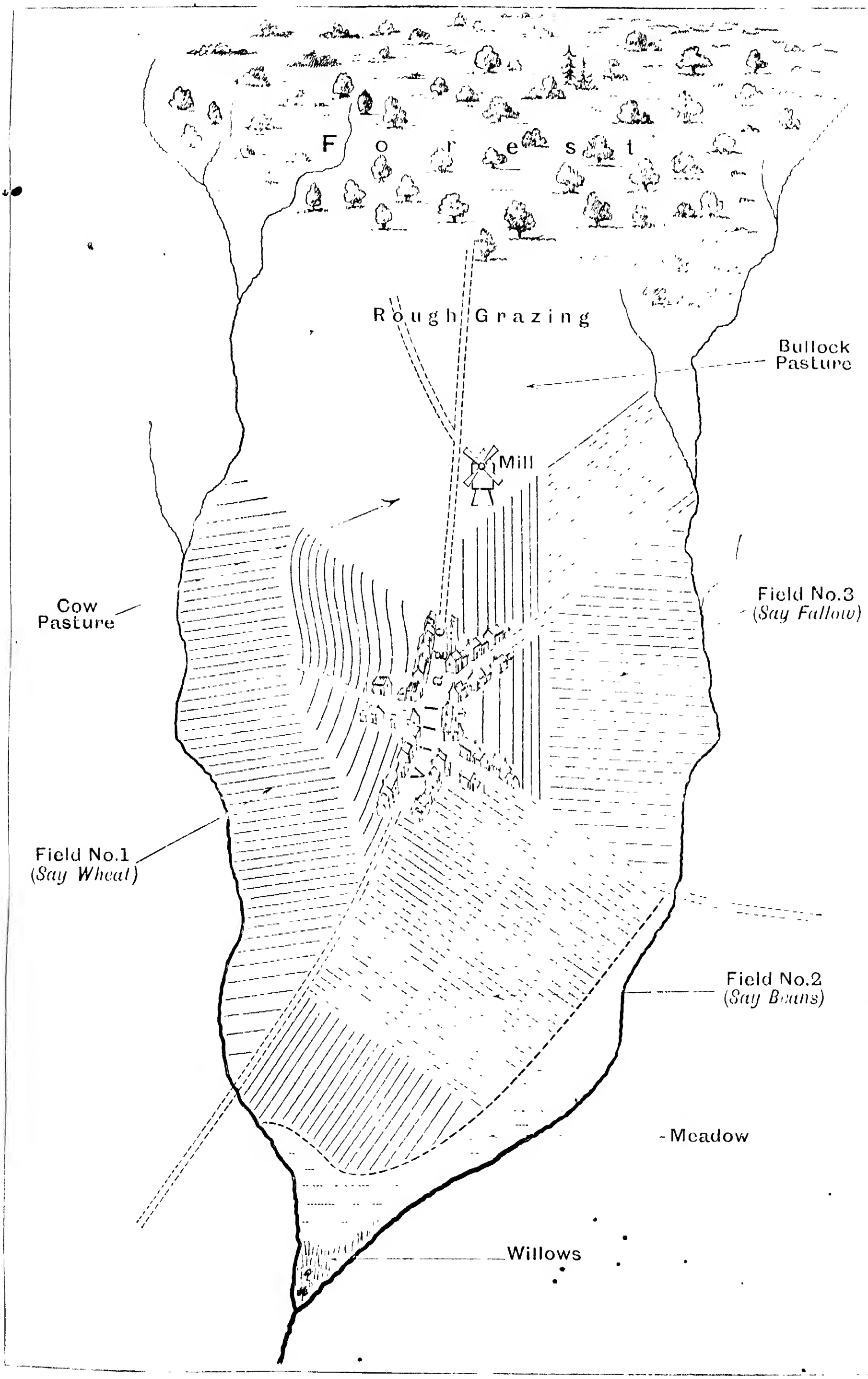


DIAGRAM OF THE VILLAGE AND ITS FIELDS

FEUDALISM.—It would be difficult to say what stage of development was reached when feudalism intervened; but at first it had little effect, although eventually it gave rise to another system which flourished alongside the old English three-field system till the middle of the eighteenth century. In early times there was little difference in rank among the Anglo-Saxons. Gradually, however, the leaders rose higher and higher, surrounded themselves with fighting-men, and compelled the villagers not only to work their land for them but to contribute also from the produce of their own fields: the lords and thanes either living at ease or waging war while the farmers toiled to supply their demands. The lord or earl, having built himself a castle beside the village of which he had become the master, allowed his thanes to build themselves homesteads beyond the village fields and to reclaim fresh land for their support. The castle and homestead lands were worked, like the village lands, upon the three-field system: only they were worked by villagers and by hired or enslaved retainers captured in war.

CHAPTER II

BRITISH AGRICULTURE AFTER THE DECAY OF FEUDALISM — JETHRO TULL'S NEW HUSBANDRY—BAKEWELL'S IMPROVED STOCK.

EFFECT OF RISE OF COMMERCE ON AGRICULTURE.—With the rise of commerce in the fifteenth and sixteenth centuries feudalism lost its hold. Landowners sought to make money rather than raise men. They still cultivated the lands round their castles and manors with their close retainers, but the rest of their land they let out to farmers for rents to be paid in money instead of in service and kind. Innovations crept in. Having been found profitable, portions of the non-village land were enclosed both for tillage and grazing purposes. The fields longest under cultivation—the in-field land—were still managed on the three-field system; but land more recently reclaimed—the out-field—was cropped for six or eight years in succession and then allowed to fall back again into pasture. Even the feudal lord's old war horse, himself an importation from the Low Countries, was being degraded to the plough and the wagon by the invention of gunpowder: his place being taken by speedier animals from the East. There were signs of impending revolution in agriculture. The weapons with which it was to be accomplished—potatoes, turnips, rye grass, and red clover—were introduced by the middle of the seventeenth century, although it took the best English farmers another century to learn their use.

BRITISH AGRICULTURE AT BEGINNING OF EIGHTEENTH CENTURY.—The beginning of the eighteenth century being the time when the foundations for the future advance were laid down, we shall do well to compare the productivity of the agriculturist of that date with that of his successor

to-day. Gregory King, the Lancaster Herald of that time, estimated that in 1696 there were 9,000,000 acres of arable land and 12,000,000 of pasture and meadow in England and Wales, while, at the same time, there was a population of 5,500,000. Assuming that between 70 and 80 per cent of the people were "engaged in agriculture", and that rather more than one in every four of these was an operative agriculturist—farmer, labourer, or elder child—then there were over a million agriculturists in the country. King's estimate of the total area of the country was too high; presumably his details also. Allowing for that, there were about 8 acres of arable land and 10 of pasture and meadow to each agriculturist. Reducing all the grain crops to wheat, the average yield was not more than 12 bushels an acre. It was even less on land cropped a few successive years and then left down to pasture. Remembering that the most productive land was cropped only two years in three, then the average yield of grain from all the tilled land was not more than 8 bushels an acre per annum. Reducing in the same way all the products of pasture and meadow to milk, and remembering that a cow gave between 200 and 300 gallons a year, and that, though assisted by straw from the tillage land, 3 acres of meadow and pasture, unimproved as they were, would barely maintain her, then the annual yield from an acre of pasture and meadow combined was about 80 gallons of milk. Thus, from his 8 acres of tillage and 10 of pasture and meadow the average agriculturist of the beginning of the eighteenth century produced about 64 bushels of wheat and 800 gallons of milk. His successor to-day in England, Wales, and Scotland together, who operates upon 29¼ acres—13.64 tillage and 15.63 pasture and meadow—produces not less than 400 bushels of wheat and 4000 gallons of milk. Besides, a very much smaller proportion of what he produces is required for seed and the upkeep of his labouring animals.

JETHRO TULL.—The greatest service ever rendered to agriculture was that of Jethro Tull, a Berkshire landowner's son, who was born there in 1674. Having studied at Oxford and Lincoln's Inn he was called to the bar in 1699; but in the same year he took to farming, and in this occupation continued till his death in 1741. Like many who abandon another profession for farming, he brought to the work an unprejudiced mind with accurate observation and clear thinking. Whether he was led up to his great theory as a farmer trying to understand his business, or as an eighteenth-century scientist trying to understand the ways of a plant, we are not told. He may have reasoned from the crop backward or from the seed and the root forward; but he came to the conclusion that the secret of the production of a successful crop was cultivation, and he expounded his theory from both ends.

Tull saw a workman using a spade among his cabbages and growing better crops than other men who used the hoe: the workman stirring the depths while others merely scraped the surface. He saw among the vine trees in the south of France the effect of cultivating the surrounding soil. He observed that the roots of a plant penetrated the soil in all directions, drawing sustenance from the surfaces of the particles they touched. He argued that the greater the total area of all those

underground surfaces, the more sustenance was offered the plant, and therefore the greater the crop. But how to increase this area, this *subterranean pasture* as he called it? By division. By breaking up the soil. Cut a loaf in two, and the surface of the bread is increased by two new faces; cut the two halves again in two, and four more faces are added, and so on. Cultivation was the secret: imitation of the man with the spade: cultivation persistent, deep, and thorough.

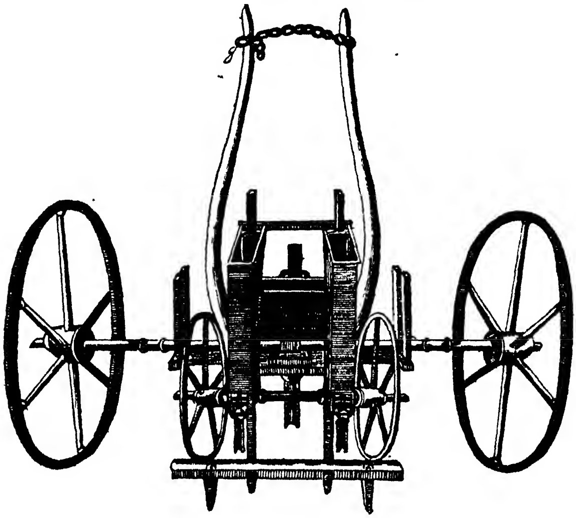


Fig. 389.—A Three-row Drill Sowing Machine

APPLICATIONS OF TULL'S THEORY — DRILLING — TURNIPS. — But though Jethro Tull's fame rests mainly upon his theory, it was not so much the theory as his showing how to use it that did the service. In Tull's time, through field crops being sown broadcast, cultivation after sowing was impossible. "The crop of wheat with irregular intervals, under the old husbandry, by being irregular, serves chiefly for the protection of weeds; for they cannot be ploughed out without destroying the corn." Tull saw that field crops must be sown in rows, and he not only invented, or at any rate perfected, a machine — the drill sowing machine—to do this, but also another—the horse hoe—to cultivate between the rows after the crop was through the ground. Thus, not only were grain and straw increased in yield, but how and where to grow the turnip was discovered. Its place was in the old fallow, whose wastefulness was now done away with, while its advantages were still retained.

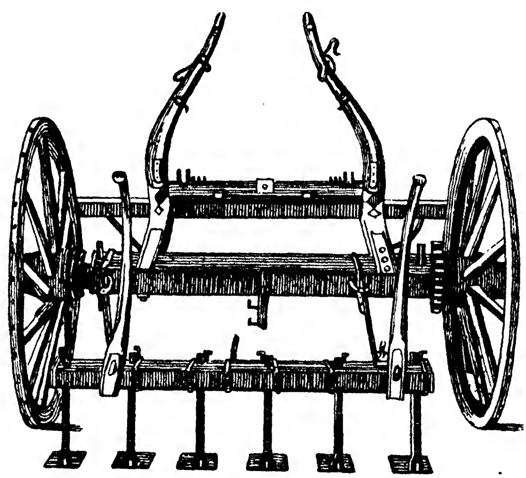


Fig. 390.—A Horse Hoe

ADVANCE OF THE "NEW HUSBANDRY".—It is hardly possible to estimate the effect of Tull's labours. He published nothing till 1731, but before then his work was known to many agriculturists, by some of

whom his methods were carried to different parts of the country, notably to Norfolk by Lord Townshend, "turnip Townshend", and to Scotland by Hope of Rankeillour and others. In time *the new hasbandry*, as it was called, spread up and down the country. The turnip was the great innovation. It was now no longer necessary to salt down the beef before winter. Cattle in Scotland need not now be helped up when they fell or lay down before the pasture came through in spring. With hay and straw increased and augmented by turnips, cattle could be fed almost as well from November to May as from May to November.

Nor was there lack of financial inducement. The population was rapidly rising. The demand for agricultural produce was increasing. Farmers were eager not only to adopt the new crops but also to extend their operations. More and more land was brought under the plough. New farms were planned and old ones extended. The old system of cropping till exhaustion was no longer practised either on newly reclaimed or on out-field land, and, on the in-field, the three-field system gave way: their places being taken by rotations which were either copies or extensions of that which sprang up first in Norfolk, viz. wheat the first year, turnips the second, barley the third, and clover, or rye grass and clover, the fourth.

ENCLOSURE OF VILLAGE LANDS.—But Tull and the new crops were the cause of a great social revolution. While turnips and red clover were finding their place among the "champain" farmers'[1] crops, the lands of the village communities were still farmed upon the three-field system. The villages had already been assailed and shaken. They were not in an impregnable position. It had been realized that enclosed and individually controlled land was more productive than the open pastures and the "mingle mangle" tillage of the village. Turnips and red clover turned the balance. The turnip might have been grown on the fallow had every member of a community been persuaded to agree; but for turnips and red clover both there was no room. A four-course rotation could not be worked upon three fields. Even if turnips could have been grown, where were the extra consumers to be pastured? Unable to acquire more pasture, the villagers were unable to grow turnips and clover. The village and its three-field system had to go. Eventually the village lands were enclosed and consolidated, so that each man's fields lay all together: the justification of the change being the wastefulness of the system and the benefit of the country. In another century few villages survived in which the old system existed.

RE-ADJUSTMENT OF FARMING CONDITIONS.—These agricultural and social changes resulted in a re-adjustment of the farming population. So far, farmers and labourers were not unequal in number. Including their elder sons, farmers were probably in the majority. Henceforth the majority is with the labourers. Enclosures and consolidations turned many of the smaller farmers into labourers, more especially those whose farms were so small that they had to labour for others, and of these, again, many migrated into the country upon the extension and improvement of

[1] Farmers whose land and homesteads were outside the village.

"champain" farming. In the nineteenth century, when farms thought large in the eighteenth were amalgamated because they were not large enough, the ranks of the labourers were still further increased.

RURAL DEPOPULATION.—The progress of commerce led to another movement, whose existence, or, at any rate, whose significance, was not realized till recent times: the movement now known as rural depopulation. Even in Saxon times ploughmen and shepherds were set aside for special work; but trade encouraged still more effective division of labour. The products of the land were no longer all consumed there, but were carried to towns to be consumed by carpenters, blacksmiths, saddlers, merchants, and others, concentrating there upon what in former times had been part of the work of their agricultural ancestors. But because the rural population was increasing, although less rapidly than the urban, the fact of rural depopulation having already begun was obscured.

IMPROVEMENT OF STOCK BY BAKEWELL.—The great discovery next to Tull's was that of Robert Bakewell, a Leicestershire farmer and grazier, born in 1725, who managed the family property from some years before his father's death in 1760 till his own death in 1795. His task in the middle was smaller than Tull's in the beginning. Had it not been for the turnip and the growth of population Tull's theory might have remained unknown until rediscovered by some German towards the end of the nineteenth century. But for Bakewell's success the ground was cleared. The winter food supply was increased; fences made it possible to keep flocks and herds apart and so prevent better being crossed by inferior animals; while increasing wealth and population demanded a greater supply and a better quality of beef and mutton.

Bakewell saw the demand, and endeavoured to meet it. He tried also to breed animals that would make better use of their food and come to the butcher at an earlier age. Hitherto bullocks had been valued chiefly for draught, sheep for wool. A bullock was not called a bullock—he was only a steer—till he was five or six years old; a wether was not fit for the butcher till he was four or five. In Bakewell's time it was the farmer's custom to send to the butcher the animals inclined to be fat, and retain the lean for breeding. Bakewell reversed the process. "It is well known that he always kept his fattest-inclined for store and sold the lean-inclined ones (if any) to the butcher, contrary to former maxims."

BAKEWELL'S CATTLE AND SHEEP—INBREEDING.—For his purpose Bakewell chose animals from the races to which the stock in his own neighbourhood belonged: Longhorn cattle, a race running from the Southern Midlands up into North Lancashire, and long-woolled, white-faced sheep, a race running across the country from Gloucester to Lincoln and Yorkshire.[1] Selecting the most suitable animals, and breeding from these, he soon raised his stock to a higher standard than any others. But, having done so, he encountered a very serious difficulty, a kind of dilemma from which there were but two escapes—one never attempted before, and attended perhaps by unknown and, therefore, fearful dangers.

[1] Bakewell was also one of the early improvers of the Shire Horse. He imported breeding stock from Holland.

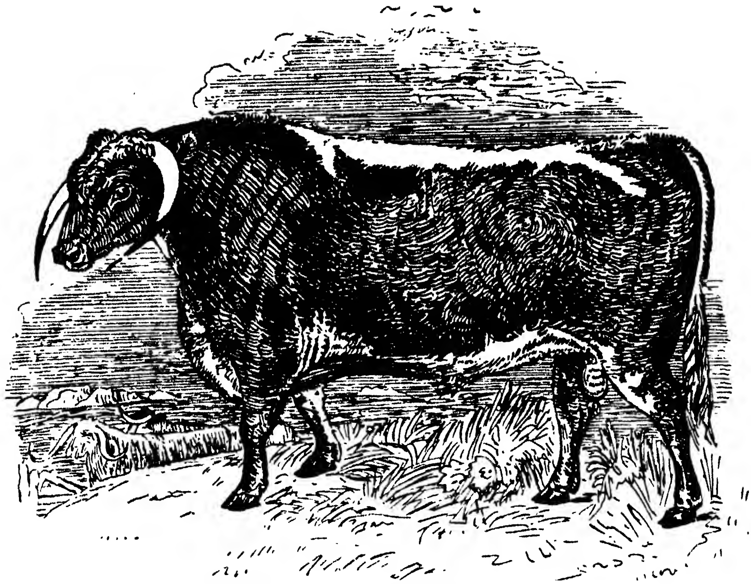


Fig. 391.—A Longhorn Bull

He must cross either with inferior stock or with animals of his own breeding. He must either give up the ground he had gained, or maintain it in face of universal prejudice and unknown hazards. He took the risk. He

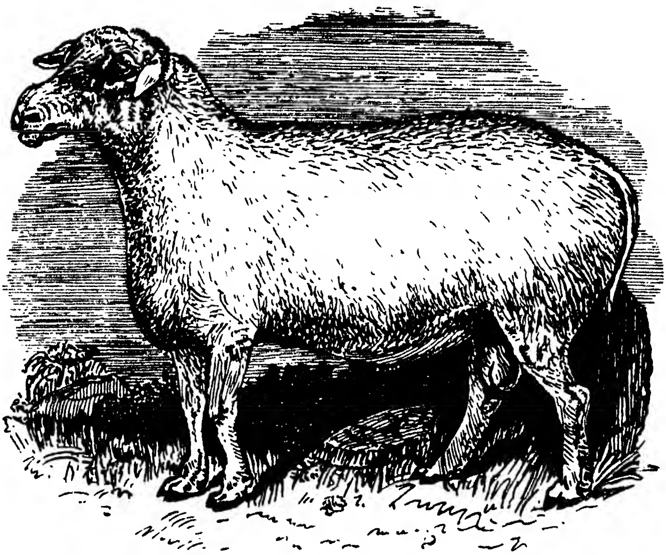


Fig. 392.—An Old Yorkshire Ram

bred with his own stock, with the result that he not only maintained but possibly improved them. At the same time he discovered for skilful breeders their deftest weapon, in-breeding, the weapon of nature herself.

Spread of Bakewell's Methods.—Considering the prejudices of the time, Bakewell's methods spread with wonderful rapidity. Tomkins began to imitate him with Herefords in 1769, the Collings with Shorthorns in 1770, Quartly with Devons about 1800, and Hugh Watson with Angus cattle in 1808. There is scarcely a British breed but has been brought forward by Bakewell's method. The general result is, that a bullock is as heavy to-day at two years as he was at five a century ago. The following diagram shows Bakewell's method of improving his stock, as

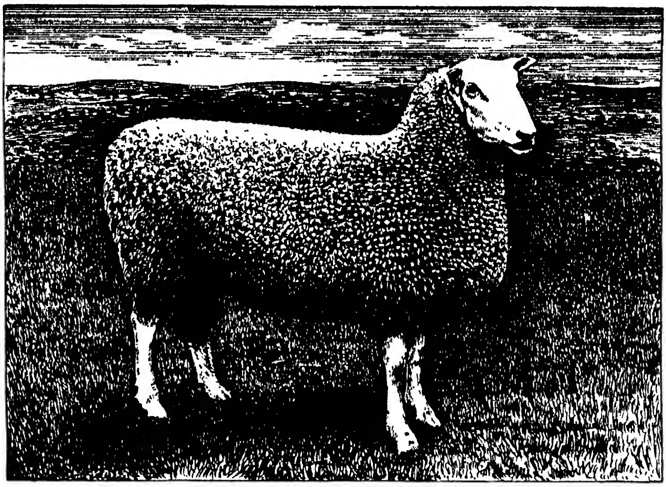


Fig. 393.—A Border Leicester Ram

brought out in the pedigrees of his own bull *D*, Charles Colling's shorthorn bull *Comet*, and Hugh Watson's Angus bull *Old Jock*:

Twopenny -
A Bakewell cow — >Twopenny's son —
>D.
Twopenny —— >Twopenny's daughter
Twopenny's dam —

Lord Bolingbroke —
Phœnix —— >Favourite
>Comet.
Favourite —— >Young Phœnix —
Phœnix ——

Black Jock ——
Old Favourite —— >Grey Breasted Jock —
>Old Jock.
Grey Breasted Jock —
Old Favourite —— >Favourite ——

Bakewell's sheep, the Leicester, forked into two breeds, the English and the Border Leicester, both still existing and still pure. For grading purposes they have been used upon all the long-woolled, white-faced breeds in England and Ireland. His cattle, the Longhorns, are now nearly extinct, not because of Bakewell, but because of their horns, and because other breeds sprung from better original materials have outstripped them.

CHAPTER III

IMPROVEMENT IN AGRICULTURAL IMPLEMENTS—DRAINAGE OF LAND

THRESHING MACHINES.—As was to have been expected, the spread of *the new husbandry* led to improvement in agricultural implements. In 1773 Sir Francis Kinloch brought to East Lothian a threshing machine invented by Mr. Ilderton of Alnwick. It was attached for a trial to the water wheel of Andrew Meikle's barley mill at Houston, near Haddington.

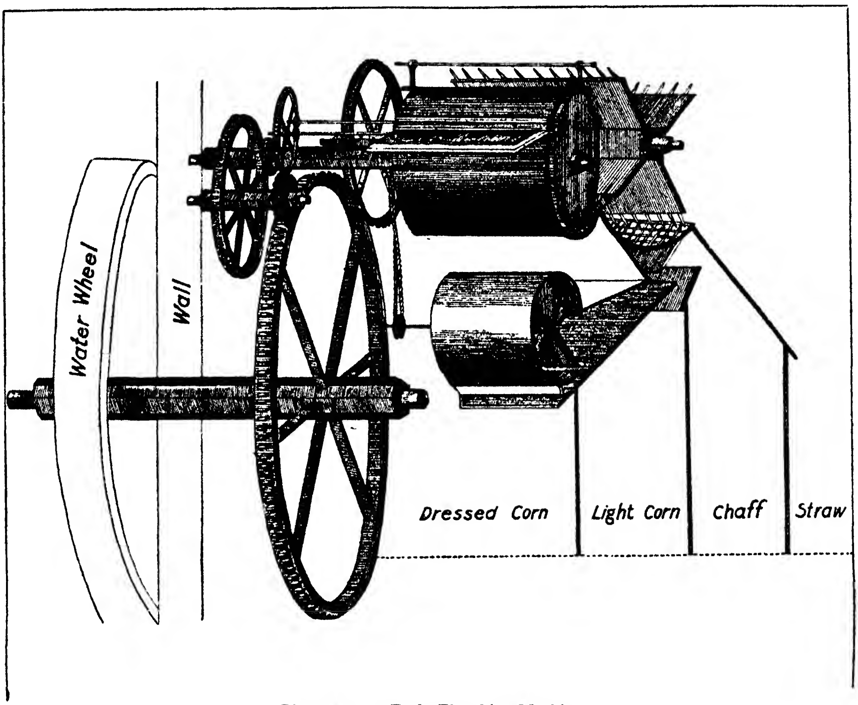


Fig. 394.—An Early Threshing Machine

"It was torn to pieces in the trial, and, when tried anew upon a larger scale, the same accident occurred." Profiting, however, by his experience, Meikle erected shortly afterwards the first successful threshing machine. Its principle of action still holds. It was, in effect, a flax mill, excepting that instead of the flax being held by hand against the flat blades or spokes of a quickly revolving wheel, which beat the woody parts of the fibre, the grain was now pushed by fluted rollers against cross bars on the rim, and so beaten out: the rim being flattened out to a drum or cylinder.

TILLAGE IMPLEMENTS—PLOUGHS.—But the greatest attention was given to tillage instruments, to instruments that would divide the soil

smaller and smaller, as Tull had suggested. Cumbrous and ill-made rollers and rude-shaped harrows and cleaving implements were greatly in use. Tull himself gave some attention to the plough, with little result, however, other than to suggest it ought to be lighter in draught. He specially recommended the Berkshire plough, obviously because, having four coulters, it was bound to disintegrate the furrow. But, like all others, its draught was excessive. Writing of ploughs in Scotland in 1777, Lord Kames says: "If we look back thirty years, ploughs of different constructions did not enter even into a dream. The Scotch plough was universally used; and no other was known. There was no less ignorance

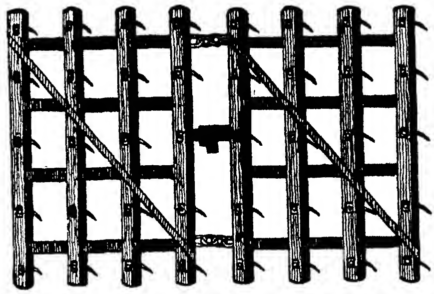


Fig. 395.—Harrows

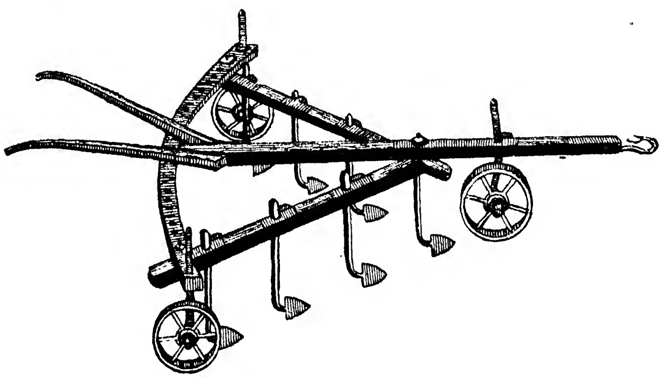


Fig. 396.—A Cultivator

as to the number of cattle necessary for this plough. In the south of Scotland, six oxen and two horses were universal; and in the north, ten oxen, sometimes twelve." So many animals were required because they

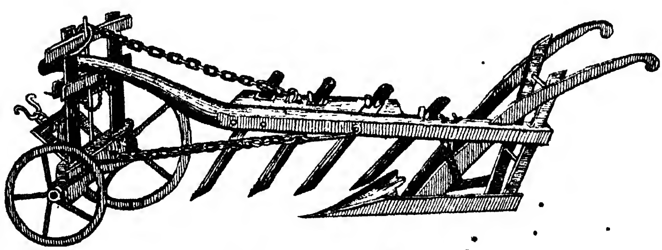


Fig. 397.—The Berkshire Plough

were ill-fed and the land was still intractable, but chiefly because of the plough itself. Excepting the share and the coulter, it was made of wood. The friction was therefore enormous, and it was increased by the great

length of the parts rubbing against the soil. Moreover, the plough being too cumbersome to be guided by a ploughman, the furrow was controlled in width and depth by two contrivances working against each other. The share was set so that the plough sought always to go deeper and wider, while these tendencies were counteracted by wheels attached to the beam. Thus it was the flat surface rather than the sharp point of the share that was hauled forward into the earth.

The old plough was displaced first by ploughs of lighter draught, like the Norfolk plough, and finally by implements of great simplicity with no wheels, in which the depth and width of the furrow were controlled by the direction of draught and by pressure of the ploughman's arms upon the stilts. The earliest of these was a plough imported from Holland, afterwards known as the Rotherham plough, but the revolutionary plough was one invented about 1764 by James Small, a Berwickshire ploughmaker. Its great advantages were that it could

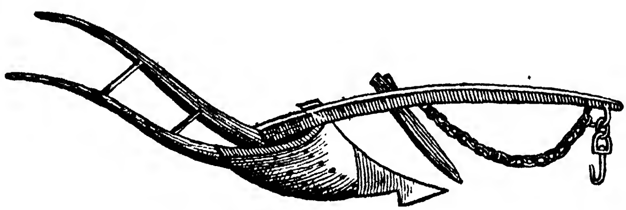


Fig. 398.—Small's Plough

be drawn by two animals, and that the ploughman could drive these himself. Thus the labour of another man, sometimes a man and a boy, and six or eight bullocks, was saved. Small's plough carried another improvement, the specially bent or twisted mould board, an improvement of the utmost importance when iron replaced wood in ploughmaking.

DRAINAGE OF LAND

During the latter half of the eighteenth century, consequent upon the population still increasing, enormous areas of fresh land were brought under cultivation. The most of this land was of a rough, moory or marshy nature. Where it was moory it was infertile till it was limed, where it was marshy it was infertile till it was both limed and drained. Liming was not a new practice, but it now increased in vogue not only upon fresh land but also upon land that had been under the plough for centuries. Arthur Young tells us in his *Tour in Ireland* (1776–8) that there were thirty-five kilns between Newtown Stewart and Portaferry in County Down, a distance of about 15 miles: "I was told thirty-five, and that fifteen years ago there was only one".

Nor was draining new, if ploughing and heaping up the land in round-backed ridges to run the water into the furrows between them, with the furrows running into an open ditch or stream at the bottom of the field, could be called draining.

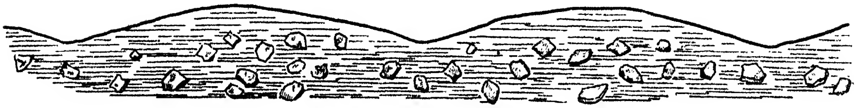
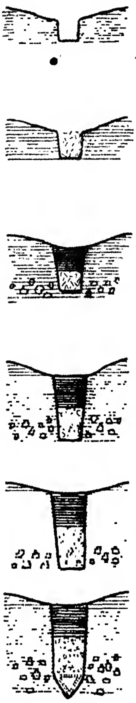


Fig. 399.—Diagram showing the Development of Drainage from the old Ridge-and-furrow System



Gradual Improvement of Drains.—In some of the eastern counties of England the ridge-and-furrow drainage system had been improved upon. A shallow track, ploughed or dug along the bottom of a furrow, lowered the water level and brought fertility farther down the ridge. But in tillage operations the sides of the track fell in and damaged it. To obviate this, it was filled up with broom, straw, rushes, or similar materials. It was found that these materials might be covered up with earth without the drainage being impaired. The next step was to dig deeper still, to knit the broom or straw into a loose rope and cover it over with a depth of soil sufficient to allow cultivation. When the drain was deep enough the furrow was found to be as fertile as the ridge. Finally, by digging the drain about 3 ft. deep, and making a channel in the bottom with stones, a drain was made that was but little improved upon till near the middle of the nineteenth century. All over the country it had become the custom to treat wet and marshy patches in a less systematic way by tapping them here and there with deep open ditches or shallower covered-in drains. But drainage was not understood.

Elkington's System.—One day in 1764 Joseph Elkington, who owned Princethorp in Warwickshire, found a drain he had cut into the side of a shaking bog was not a success: it was not deep enough. Seizing a punch from a workman, he drove it 4 or 5 ft. deeper, to see the character of the soil below. The punch showed the soil to be soft, and therefore easily dug, but on being withdrawn the punch was followed by a stream of water which continued for a long time. Had no water followed the punch Elkington would have dug deeper; now, however, he let the water flow. He argued that the bog must be the surface of an irregular well reaching down into the earth, spreading out beneath the surrounding land, but held in by the tenacity of the walls of rock and soil. Withdrawing the punch was like withdrawing the bung from a barrel. Here was a method of dealing with wet or marshy spots on higher or sloping ground. All that had to be done was to find the bung-hole and lead the issuing water away in a drain or ditch. This was not always easy, but Elkington invented a boring auger 30 ft. long for the purpose. This method of draining was not applicable to level ground, but Elkington solved the problem. Since water collected over clay, or some other impervious

bottom, the plan was to sink holes through these impervious layers to porous or pervious layers below. So, with its bung-holes and its sink-holes, the Elkington system held the field for many a day. It has been

Section

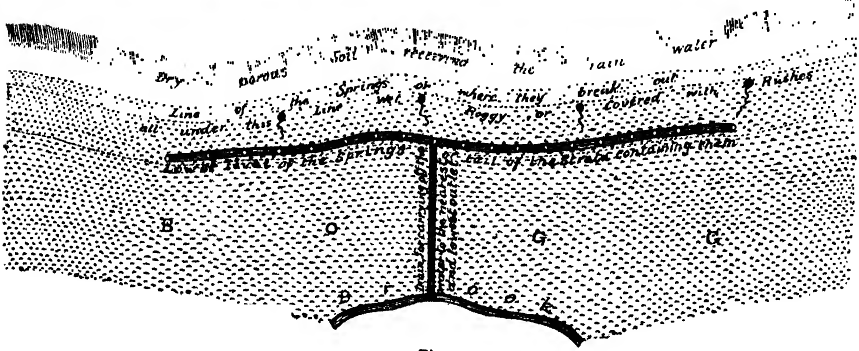


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Fig. 400.—Elkington's System of Draining Sloping Land

argued that the system was discovered first by Dr. James Anderson of Aberdeen, but it was Elkington who developed it.

"Being a man of considerable natural ingenuity, though it is said of

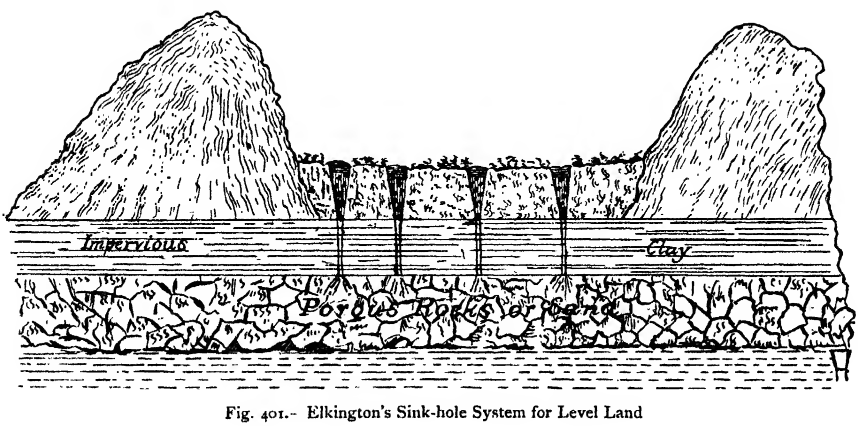

Fig. 401.- Elkington's Sink-hole System for Level Land

little literature, he had the address to take advantage of the discovery he had made with a view to the improvement of his affairs. He therefore commenced the trade of a drainer in land; and by the novelty of draining by a small hole bored often at a considerable distance from the wettest

part of it, and by conducting himself in a mysterious manner, he acquired great reputation and was extensively employed. This employment he appears to have merited, as his operations were attended with very great success. After the establishment of the Board of Agriculture, its members, who appear to have been unacquainted with Dr. Anderson's publication, supposed Mr. Elkington to have been the only discoverer and possessor of the art of draining land wet by springs in the way now mentioned; and upon their recommendation Parliament bestowed a reward of £1000 upon him [1795]."

SMITH'S SYSTEM.—But this was not draining. It was mere leeching or blood-letting. The problem was first understood by James Smith, a factory manager at Deanston near Doune in Perthshire, to whom it was presented in the shape of a small "rush-grown, moory" farm attached to the factory. This farm had to be drained, and Smith devised a system of his own. How clearly he understood the problem; how clearly he saw the defects of Elkington's and the ridge-and-furrow or "Essex" system will be shown by a few quotations from his *Remarks on Thorough Draining and Deep Ploughing*, first printed in 1833 in Drummond's Report of the Agricultural Museum at Stirling. Smith's system was to have drains of equal depth—2 ft. to 2 ft. 6 in.—running up and down the field at equal distances parallel to each other. The distances between the drains were not to depend upon the breadth of the ridges, as in the Essex system, but upon the character of the soil. They were to be from 10 to 15 ft. for stiff strong till and dead sandy clay, 18 to 24 ft. for a lighter and more porous subsoil, and even up to 40 ft. for very open soils. Smith maintained there was no need for ridges to throw off the water, but that the surface should be level. The water would then sink evenly through the soil. "Besides, it is probable that the reaping machine will, ere long, become a powerful auxiliary implement of the harvest.

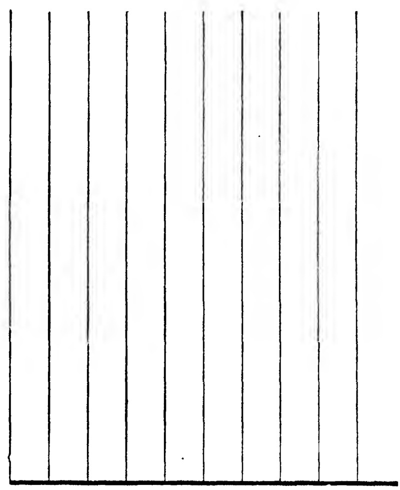

Fig 402.—Smith's System of Drainage

"When soil is immediately incumbent on open rock, especially on whin or green stone, which is very open from its many fissures, the land is uniformly fertile. . . . The open rock under the soil affords frequent and pretty uniform channels of escape for the water; hence the obvious suggestion of the *frequent drain system*. . . .

"The principle of the system . . . is *the providing of frequent opportunities for the water rising from below or falling on the surface, to pass freely and completely off*.

"The drains should run parallel to each other, and at regular intervals, and should be carried throughout the whole field without reference to the

wet or dry appearance of portions of the field, as *uniform and complete* dryness is the object; and portions of the land which may be considered dry in their natural state will appear wet when compared with those parts which have been properly drained."

With regard to Elkington's system Smith wrote: "The principle of this mode was to make perforations or bores, or to dig under the strata, so that the water might pass from an impervious to an open stratum. To those who know anything of the nature and structure of the superficial stratification of the crust of the earth in this country, this principle must, of course, have appeared of very limited and uncertain application; nevertheless it was all the rage for a time, and much money was thrown away in its application under circumstances not at all suited to the principle. The

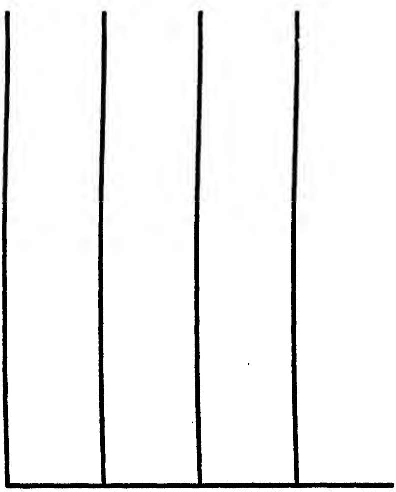

Fig. 403.—Parkes's System of Drainage

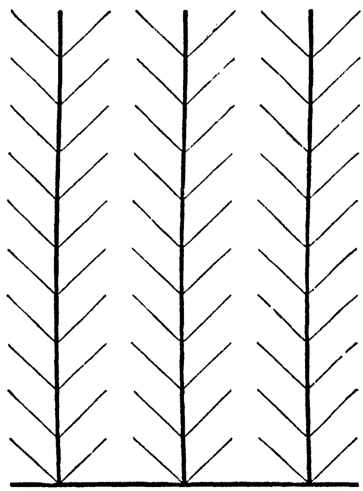

Fig. 404.—The Herring-bone System of Drainage

portion of land wetted by water springing from below bears but a very small proportion to that which is in a wet state from the *retention* of that which falls upon the surface in the state of rain." Much wider and deeper drains were advocated by Parkes, the engineer to the Royal Agricultural Society of England. A compromise between Smith and Parkes was proposed in the herring-bone system, in which very deep drains, widely apart, were run up a field and frequent shallow drains were led into them on either side. Very soon, however, draining settled down on Smith's Deanston system, excepting that the drains were deepened to 3 ft. or 3 ft. 6 in.

The general principles of drainmaking being now established, it still remained to improve the methods and materials of construction. The stone drain was not unsatisfactory if the channel were well laid. It was expensive, however. The digging of a trench 12 or 14 in. wide below, and 16 or 18 at the surface, cost a lot of money, let alone collecting, breaking, and shaping the stones to fill up the bottom 10 or 12 in. But how was a drain to be built when stones were not to be had? The difficulty was got

over in many ways, finally in such a way as to solve the whole problem. Drains were dug **V** shaped at the bottom, and plugs of clay were wedged in just far enough to leave the apex of the **V** vacant, which thus formed a channel. In other cases a notch was cut along the bottom of the ordinary drain and covered over by a sod or a lump of clay before the drain was refilled. Earthen tiles, arched or horseshoe-shaped, came into use about

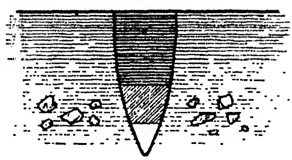

Fig. 405.—V-shaped Clay Drain

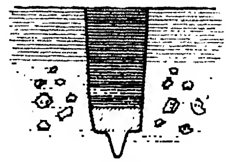

Fig. 406.—Notched Clay Drain

1820. They were laid into the drain edges downwards, either directly or upon a flat stone. Flat earthen plates or soles were substituted for the stones about 1839.

READ'S TILES.—At the Southampton show in 1844 the Royal Agricultural Society of England, which had invited exhibits of tiles and tile-making machines, awarded a silver medal "to Mr. John Read, 35 Regent

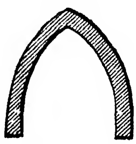

Fig. 407.—Arched Drain Tile

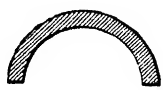

Fig. 408.—Horse-shoe Drain Tile

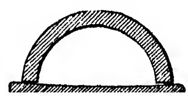

Fig. 409.—Horse-shoe Tile and Flat Sole

Circus, London, for specimens of cylindric or pipe tiles invented by him". Read's tiles were invented thirty-five years before, but he only now realized their importance. He "made and employed them when farm servant to the late Rev. Dr. Marriott, of Horsemonden in Kent. These original pipes were about 3 in. diameter in the bore, and were formed by bending a sheet of clay, as usually prepared for the common drain tile, over a wooden cylin-

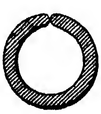

Fig. 410.—Read's Drain Tile

Fig. 411.—Cylindrical Drain Tile, 1 in. diameter

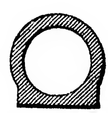

Fig. 412.—Cylindrical Drain Tile, 2½ in. diameter

dric mandrel. In consequence of the imperfect union of the two faces of the clay, a narrow slit was left throughout the length of the tile, which served, and was then thought necessary, to admit the water. They were found to act well, but their use did not extend so rapidly as it might otherwise have done had not Mr. Read quitted his farming employment to devote himself, in London, to the manufacture of his celebrated stomach pump and other surgical and veterinary instruments. Tiles on this plan

have been made during the last three years in the parish of Saylherst in Sussex."

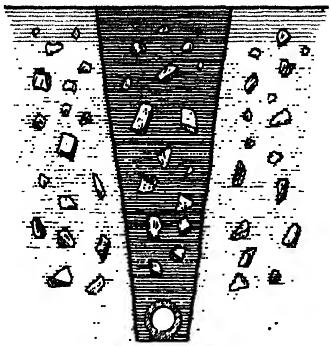

Fig. 413.—Cross Section of a Modern Drain

TILE-MAKING MACHINES.—All that was wanted now was a machine to make cylindrical tiles, and that was forthcoming, the invention of Thomas Scragg, of Calveley, in Cheshire, and others, at the Shrewsbury show in 1845. Since that time tiles "made by machinery which squeezes out clay from a box through circular holes, exactly as macaroni is made in Naples", have displaced all other materials. For a while cylindrical tiles were made too small; but eventually their usual size became 2½ or 3 in. diameter, and their external surface was flattened on one side to prevent displacement in the drain.

CHAPTER IV

IMPROVED CROPS AND STOCK—MANURES

Towards the end of the eighteenth century, when Britain was first confronted with the question of her food supply, and prices were rising, farmers displayed a readiness to try more new crops, and to cultivate improved varieties. Swedes and mangels were introduced about 1786, potatoes extended as a field crop, and the less-productive varieties of grain, such as bere, the grey oat, *Avena strigosa*, and the wild oat, *Avena fatua*, passed slowly out of cultivation. Of the varieties retained we know but a few names. Of their origin and history we know nothing. We can only surmise that previous improvements had been effected similarly to the one first recorded. According to the account which is supported by the strongest circumstantial evidence, an oat plant of outstanding character was found in a potato field in Cumberland in 1788. Its seed was saved and sown and re-sown from year to year till a supply accumulated. Eventually it became the most widely cultivated variety in Britain.

IMPROVED VARIETIES OF KNIGHT AND SHIRREFF.—The earliest systematic raiser of new varieties of grain was Thomas Andrew Knight, a noted horticulturist, who "readily obtained as many varieties as he wished by merely sowing the different kinds together"; but the most important was Patrick Shirreff, an East Lothian farmer. "When walking over a field of wheat on the farm of Mungoswells, in the county of Haddington, in the spring of 1819, a green, spreading plant attracted my notice, the crop then looking miserable from the effects of a severe winter; and next day measures were taken to invigorate its growth by

removing the surrounding vegetation and applying manure to the roots. In the course of summer several stalks were cut down by hares; but, notwithstanding this loss to the plant, sixty-three ears were gathered from it at harvest, yielding 2473 grains, which were dibbled in the following autumn at wide intervals. For the two succeeding seasons the accumulating produce was sown broadcast, and the fourth harvest of the original plant amounted to about 42 qr. of grain fit for seed; and proving to be a new variety, it was named Mungoswells Wheat."

The Hopetoun Oat was similarly discovered in 1824, and for fifty years more Shirreff continued to raise new varieties of wheat and oats, many of which, under their original or other names, are still in cultivation. About the middle of the century he tried to raise new varieties by artificial cross-fertilization, but with less success. He explains why: "My selections have chiefly been from natural sports, which soon show their propensities, and often prove constant, having in all probability undergone reproduction before being selected. . . . Sports may be regarded as the gift of nature to man."

Hallett and Paterson.—Shirreff has had many successors, the most notable being Hallett, because of his method, and Paterson, of Dundee. Hallett's was Shirreff's early method intensified. When Shirreff discovered a good plant he at once accumulated all its progeny. Having selected a parent, Hallett saved seed only from the best plant of its year for four or five successive years before beginning to accumulate. That is to say, having selected a head of wheat in 1857, he kept seed only from its best child in 1858, from that child's best child in 1859, and so on.

Paterson dealt with potatoes. His method was cross-fertilization. He collected parent potatoes from many parts of the world, and endeavoured, by uniting different kinds, to produce new varieties, for which an opening had just been made by the great famine. Many of the varieties at present in vogue are cultivations from Paterson's strains.

IMPROVED STOCK

It was pointed out that the ground was cleared for Bakewell by Jethro Tull and his school. The following century continued Bakewell's work. He shortened the fattening animal's age; the nineteenth century made it still shorter. Several circumstances contributed to this end. Replaced by the horse for draught, a bullock was now prepared for the butcher at five years old instead of being sent to the plough. And if fattened at five, why not at four or even less? Why not anticipate nature? Increasing wealth demanded finer and younger beef. The invention of the hydraulic press in 1795 furnished means to supply it.

Artificial Feeding Stuffs.—In the eighteenth century "artificial" feeding stuffs were unknown. Very young calves were weaned upon barley or oatmeal gruel or linseed "jelly"; a fattening bullock or cow sometimes got a sheaf of unthreshed oats or a handful of meal or bran, but the practice was not common. After 1795, however, linseed cake

came slowly into use. Possibly it was in use before that date, if not in Britain, at any rate in Holland; but the old hand press could not have provided a large supply.

SMITHFIELD SHOW.—On the formation of the Smithfield Cattle and Sheep Society, on the 17th of December, 1798, it was decided to give a prize to the best cattle beast "fed on corn or oilcake" and another "to the best sheep from corn or oilcake"; but that oilcake was still new may be gathered from the fact that the following year at their annual meeting the Bath and West Society voted the thanks of the society to the Earl of Peterborough "for exhibiting a fat ox of extraordinary size and figure,

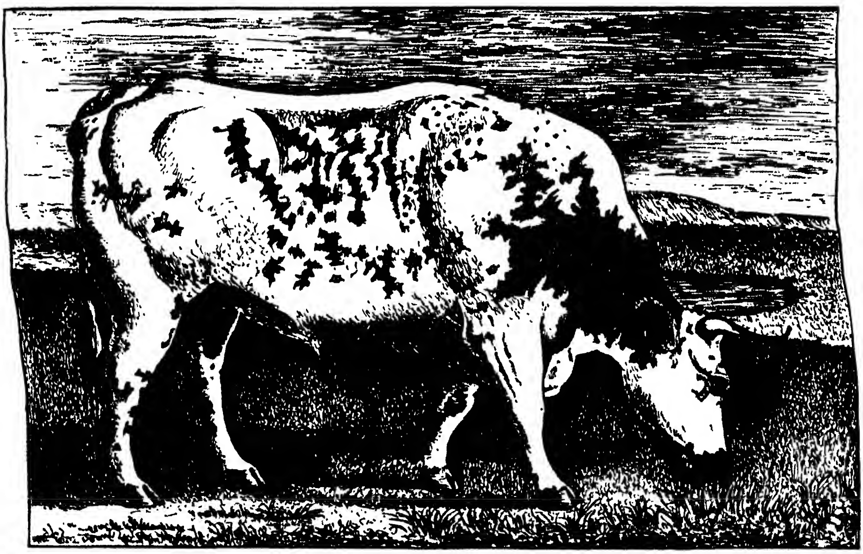

Fig. 414.—Draught East Country Bullock—eighteenth century

but which, on account of his having been fed with oilcake, could not be in competition for a premium".

The Smithfield and other shows led not only to a demand for concentrated feeding stuffs, but also to the provision of better and more comfortable accommodation for stock of all kinds. Provided at first for pure-bred and exhibition stock these things were extended gradually to ordinary stock. Both food and time were saved, and the total head of stock was increased. Cattle taken from the pastures in autumn could be fattened ere midwinter, while food which they would have required in former years remained behind now for others. Growing stock stood no longer starving and staring behind a hedge, but throve and profited beneath a roof.

COTTON-SEED AND OTHER CAKES.—Shortly after the middle of the century cotton-seed cake was introduced, and, since the great fall in prices thirty years ago, beans, peas, barley, maize, and many other grains and by-products from flour mills and food-manufacturing concerns have

been placed at the farmer's disposal. The result has been that the age at which a bullock may go to the butcher has been reduced from six or seven years to less than two, a wether may be fed off well under the

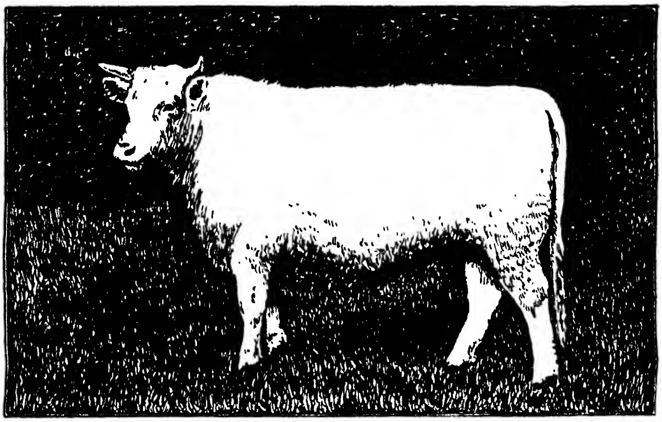

Fig. 415.—Fat Shorthorn Bullock under Two Years Old—twentieth century

year, a cow's yield has been doubled, and other live stock exist under similar possibilities.

MANURES

For the first quarter of the nineteenth century farmyard manure was almost the only fertilizer. Other substances, such as seaweed, hedge and ditch clearings, peaty matter, fish, slaughterhouse and other refuse, and even oil were in occasional use. The dung heap was "bottomed" with all kinds of rubbish and "turned" again and again before application. Rape and other oilcakes, malt dust, spent bark, wood and peat ashes, burnt clay, marl, soot, and gypsum were sometimes spread upon the land. In his lectures for the Board of Agriculture, delivered between 1802 and 1812, Sir Humphry Davy mentions phosphate of lime, magnesia salts, sulphate of potash, and bones; but the last-named of these substances was the only one in use, and that only in places.

BONE MANURE.—The fertilizing powers of bones are said to have been "accidentally discovered by a Yorkshire fox hunter in 1767". Whoever was the discoverer, their use as a manure developed first in South Yorkshire and the neighbouring counties. In a few years "they were a very common manure in the neighbourhood of Sheffield". Bone dust, "ground by mills on purpose", was used in Nottinghamshire before the century was out, and "upon all the fields for twenty miles round Sheffield". According to the *Complete Farmer*, published in 1807, "at Sheffield it was a trade to grind bones for the farmer", and the same volume also states that "the common way of treating them is to break them with a mill into pieces the size of a marble or nutmeg; they are afterwards laid upon the land in small heaps, at regular distances, and covered with earth; after remaining in this state for some time they are spread on

fallows, or grass, or on turnip land". Sir Humphry Davy says they "are much used as a manure in the neighbourhood of London. After being broken and boiled for grease they are sold to the farmer. The more divided they are the more powerful their effects." He suggested they should be ground in a mill and sown with the seed in the same manner as rape cake. Bone-crushing mills sprang up here and there, especially at places like Hull and Dundee, where bones were imported from abroad. But crushed bones and bone dust were a mere prelude to the development in the use of artificial manures about to result from the work of John Bennet Lawes, of Rothamsted, and Liebig.

LAWES.—In 1837 Lawes, who had been experimenting with plants from the materia medica point of view, commenced some pot experiments with agricultural plants. "These experiments were continued on a larger scale in 1838 and 1839. Spent animal charcoal[1] was then a waste product, and Mr. Lawes was asked by a London friend if it could be turned to any use. He therefore employed it as a manure in his pot experiments, and discovered that if previously treated with sulphuric acid its efficacy as a manure was greatly increased.

"Apatite and other animal phosphates were soon treated in a similar manner, and the 'superphosphate of lime' thus prepared was found to be most effective as a manure, especially for turnips. The new superphosphate was employed on a large scale for crops on the Rothamsted farm in 1840 and 1841, and the results were so satisfactory that in 1842 Mr. Lawes took out a patent for the manufacture of superphosphate."

In 1843 Lawes erected the first chemical-manure factory at Deptford. Coprolites had been discovered by Professor Henslow at Felixstowe in 1842, but the English supply was only small and Lawes looked abroad for his raw materials. Since 1843 large supplies of mineral phosphates have been discovered in various parts of the world, and the superphosphate industry has so increased that there are now many factories in Britain producing together over a million tons per annum.

LIEBIG.—Liebig's *Organic Chemistry in its Applications to Agriculture and Physiology* was published in German and English in 1840. Liebig suggested that bones should be treated with sulphuric acid. "The form in which they are restored to a soil does not appear to be a matter of indifference; for the more finely the bones are reduced to powder and the more intimately they are mixed with the soil, the more easily are they assimilated. The most easy and practical mode of effecting their division is to pour over the bones, in a state of fine powder, half their weight of sulphuric acid diluted with three or four parts of water, and after they have been digested for some time to add one hundred parts of water, and sprinkle this mixture over the field before the plough." Trials of the new manure—"sulphuric acid and bone dust"—were made in Banffshire and Morayshire in 1842, and there and elsewhere next year. It turned out to be a better and, since a smaller quantity sufficed, a cheaper manure than bones. On the larger farms it came quickly into use. The farmer brought home bones from the mill just as before,

[1] From sugar refineries.

and dissolved them in the way suggested by Liebig. His difficulty was to get the "gruel" thin enough for distribution. He then tried to make it a dry substance, but with only a little more success. Finally, on the expiry of Lawes's patent, the making of dissolved bones was taken over by the professional manure manufacturer.

OTHER MANURES.—But other "portable" manures were discovered. Nitrate of soda and guano were brought to the country in 1830 and 1839; the value of the potash deposits round Stassfurt in Germany was realized in 1859; and a few years after the invention in 1878 of the Thomas-Gilchrist process for converting pig-iron into steel it was found that the slag or waste left over contained phosphate of lime greater in quantity than in ordinary superphosphate, and, if well ground, almost equal in manurial value. Since 1840 artificial manures have raised the productivity of average land 30 to 40 per cent: the root crops being most affected. A dread has arisen lest one day soon we may be faced with a nitrogen famine. The South American guano beds are worked out; the annual output of nitrate of soda approaches two million tons, and the source is by no means unlimited. But the gas-works are turning out more and more sulphate of ammonia, and it has been found feasible to produce calcium nitrate and calcium cyanamide in commercial quantities, the nitrogen being extracted from the air. Through channels such as these, and from sources at present untapped or going to waste, the demand will be met when it arises.

CHAPTER V

MODERN MACHINERY—EXPANSION OF BRITISH AGRICULTURE

REAPING MACHINES.—In the eighteenth century mechanical minds were turned to the plough, the drill, the horse hoe, and other tillage implements; in the beginning of the nineteenth they were bent upon the invention of a reaping machine. For many years inventors were embarrassed by three ideas, some by one, some by all three, arising out of their conception of a reaper as a thing that must do its work like a scythe. It must cut the crop with a swinging or circular motion, deliver it in a swathe at the side, and it must be propelled from behind.

BOYCE'S REAPER.—In the earliest machine, Boyce's, the cutting was done by a series of short scythes fixed on the rim of a revolving frame which was pushed forward into the crop. A circular, revolving cutter, the edge of which was toothed like a saw, replaced the scythes in the next machine, Plunket's. In 1806 Gladstone, a millwright in Castle-Douglas, got rid of the idea that a reaper must be pushed, and, shortly afterwards, Salmon of Woburn substituted a kind of clipping arrangement for the circular disc.

OGLE AND MANN'S REAPERS.—The first inventor to get rid of two

of the three ideas at once was Ogle, of Renington, near Hawick, who, in 1822, invented a machine which was pulled, and whose cutting apparatus was the germ of that now in universal use. It consisted of "a light frame, whose front bar was of iron, and armed with a row of teeth 3 in. long, projecting forward; immediately upon these teeth lay the cutter, a straight-edged steel knife. . . . By a motion from the carriage wheels this knife was made to vibrate rapidly from right to left." Had Ogle got rid of the third idea, the reaper as we now know it might have been twenty years older. At Kelso, in 1832, Joseph Mann, of Raby, in Cumberland, exhibited a promising machine which was pulled, but, being an amateur mechanic with small capital, his machine was soon forgotten, like the others.

SMITH'S REAPER.—Two of the early machines are of unusual interest,

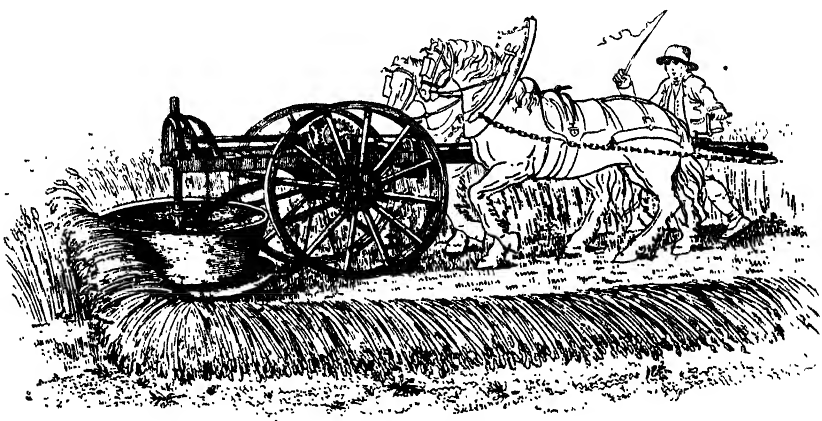

Fig. 416.—Smith's Reaper

one invented by Smith of Deanston, and the other by Patrick Bell, a Forfarshire divinity student. The idea of inventing a reaper occurred to Smith in 1807. In 1810 he made a model, and in the harvest of the following year a small machine pushed by two men was tried. The Dalkeith Farming Club offered a premium of 500 guineas "to the person who should produce an effective reaping machine", and Smith competed unsuccessfully with a one-horse machine in 1812. The following year he competed with a two-horse machine, and, although the premium was not awarded, he was presented with a piece of plate, value fifty guineas. Still improving his machine, Smith tried it in 1815 in fields of oats and beans before a committee of the Highland Society of Scotland, and was presented with another piece of plate, value fifty guineas. So late as 1835 Smith showed his reaper working at Ayr during the Show of the Highland Society. Yet it did not pass into use. It was hampered by all three ideas. It was pushed before the horse, the crop was cut by a revolving sharp-edged disc and delivered in a swathe at the side by a revolving drum fixed over the disc.

BELL'S REAPER.—Bell's machine, invented in 1826, was the first that

met with success. It was manufactured and sold in some number, and a few were exported to America. Yet Bell's machine was hampered by two of the three ideas. It was pushed from behind and the crop was delivered at the side. But the cutting apparatus was a row of shears or clippers fixed to a bar in front of the machine. One blade of each clipper

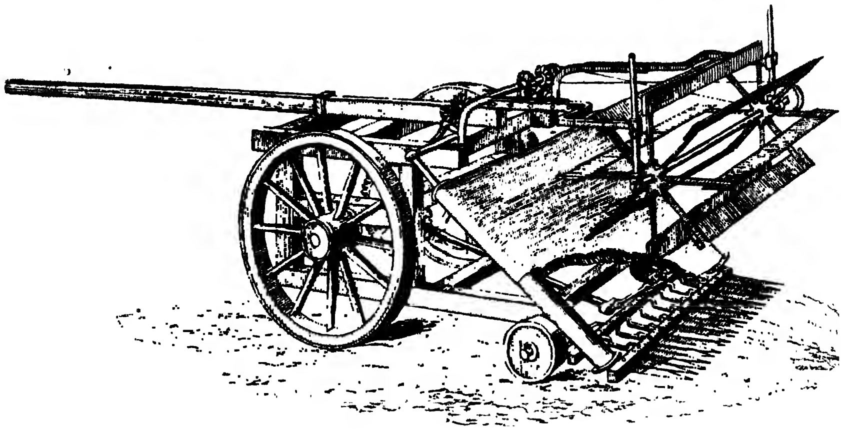

Fig. 417.—Bell's Reaper

was rigid while the other was moved upon it by a rod moving to and fro behind the bar. The crop fell on to a continuous web, by which it was laid in a swathe at the side. But even Bell's machine was before its time. The old land ridges, laid up before Smith taught thorough draining, were not yet flattened out so that the reaper could perform.

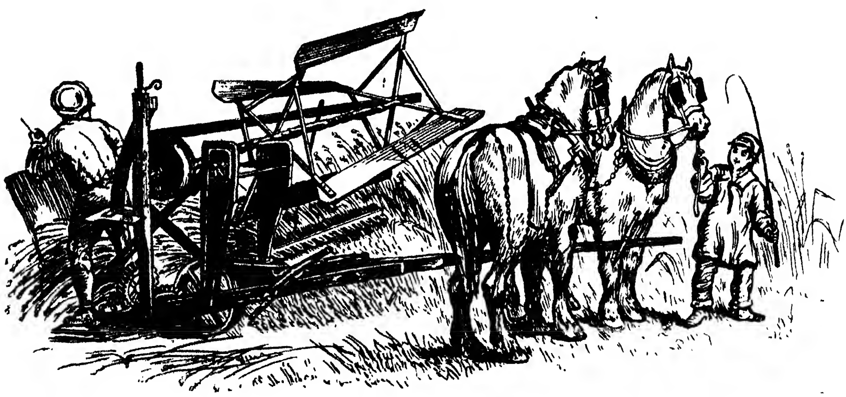

Fig. 418.—M'Cormick's Reaper

It was not till 1851 that the reaper got a footing in the farmer's mind. At the great exhibition of that year two American machines, M'Cormick's and Hussey's, both of which had got rid of all three ideas, were shown. Both were drawn, their cutting blades worked with a to-and-fro motion like Ogle's of 1822, and the crop was delivered behind by a man sitting

or standing on the machine. Public trials of these and other machines were made in the Exhibition and succeeding years, and at a trial in 1852 a Bell machine which had already cut down fifteen or sixteen harvests gained the first award. Bell's machine was a better and more economical worker, but the American machines were pulled and they

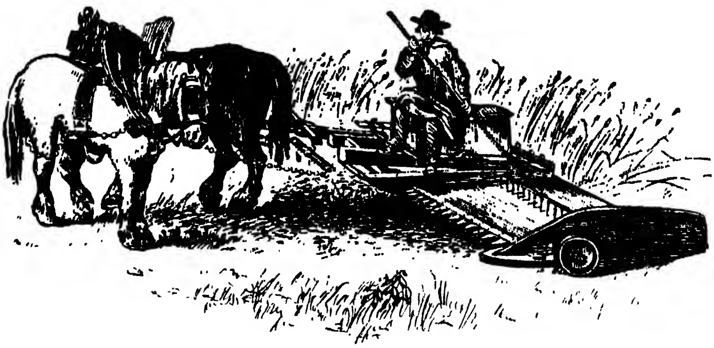

Fig. 419.—Hussey's Reaper

delivered behind. In a few years more the reaping machine was working from one end of the country to the other. Its introduction reduced the harvest in time and expense by more than a half. And, since 1877, when M'Cormick's and other self-binders came over, the cost of harvesting has been coming down further—further, however, in America than in Britain,

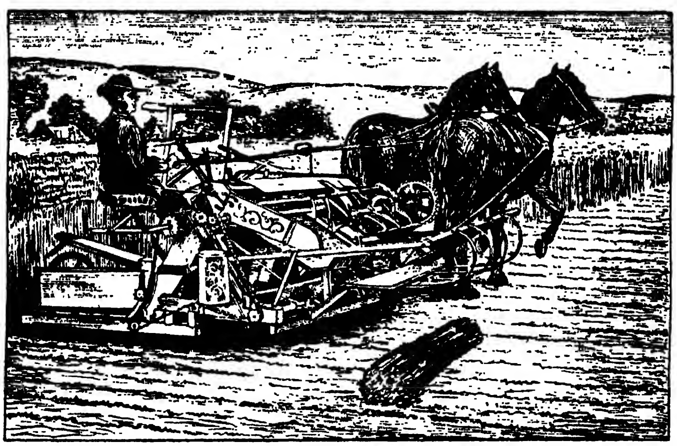

Fig. 420.—A Self-binder

where the crops are too heavy and the fields too small for the great combined harvester and thresher now in use on large American farms. Other implements in existence before the reaper have been similarly improved. The plough, the harrow, the cultivator, the sowing machine, the roller, the rake, the threshing machine, the chaff-cutter, and the root-slicer are not only more efficient but operated with a smaller expenditure of energy.

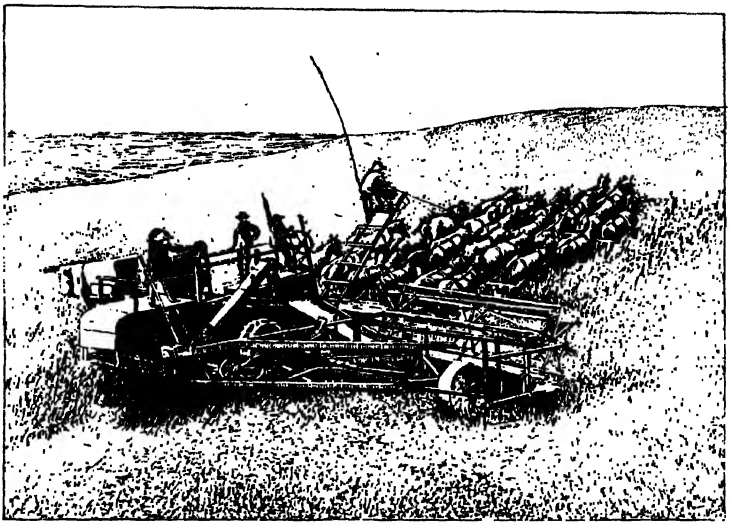

Fig. 421.—An American Reaper and Thresher

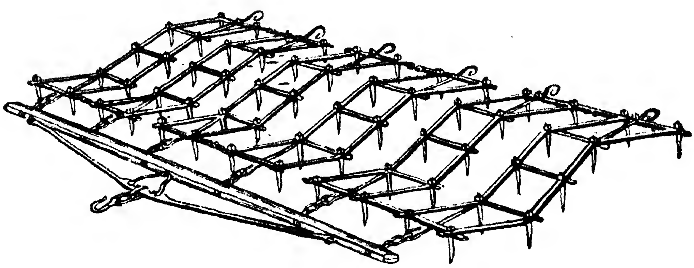

Fig. 422.—Zigzag Harrow

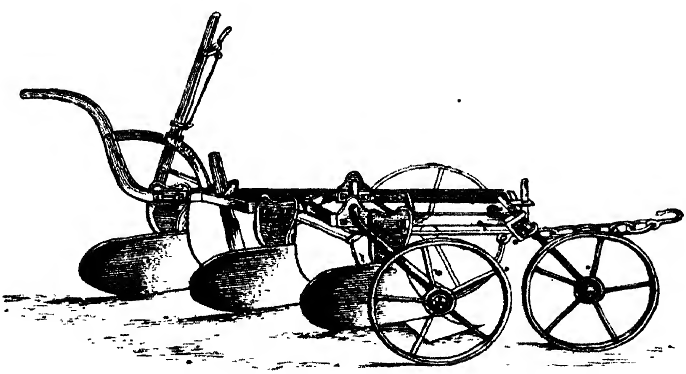

Fig. 423.—A Triple Plough

To many of them the multiple principle has been applied without extra man or horse. A man with two horses can now draw three or four light furrows where formerly he could draw but one. Barn and other inside machinery, more especially that for the dairy, has been greatly improved. Steam, applied first to an East Lothian threshing machine in 1803, has been applied to the plough and other tillage implements, to food-preparing machinery, and to the dairy.

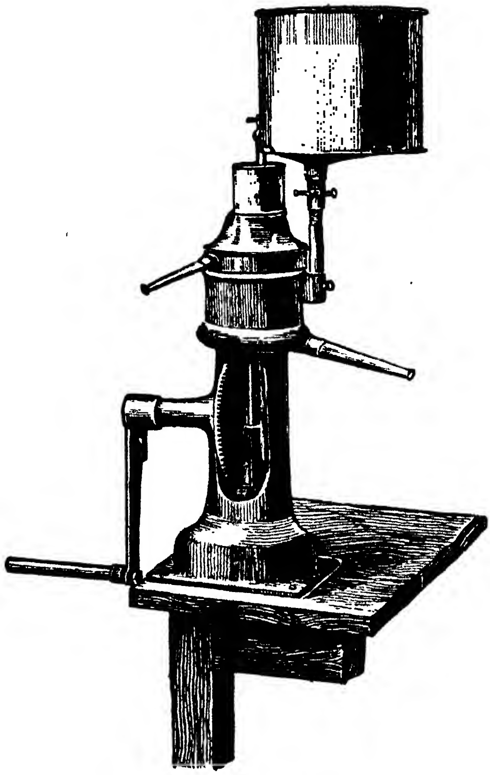

Fig. 424.—A Cream Separator

For small mobile machines, and operations in which it cannot be used so profitably, steam is being replaced by oil. Both may soon find a competitor in electricity. Many new machines have been invented since the reaping machine, among which the following are prominent: The potato digger and sorter, the hay tedder, the hay press, the rick shifter, the hay fork, the horse clipper and the sheep shearer, the milk separator, the spraying machine and the milking machine, all tending to reduce the cost of production and drive the agricultural population off the land.

EXPANSION OF BRITISH AGRICULTURE

The development of British agriculture during the last two centuries has been marvellous. Two hundred years ago the average annual yield of wheat was about 8 bushels an acre, and there were about 8 acres of tilled land and 10 of pasture and meadow to each agriculturist. To-day the average yield is four times as high, and, on well-managed farms in the east of England and Scotland, there are often 50 acres of land to each workman, all tilled. That is to say: as a producer, the good agriculturist of to-day is worth ten or twelve of his ancestors of two hundred years ago.

EDUCATION.—It has been the function of education, more especially of agricultural education, to instruct the farmer in the advances made in his profession; but, although much has been done with regard to manures, feeding stuffs, dairy work, improved crops and seeds, no instructor can extend the boundaries of a farm so that it shall make full use of division

of labour and labour-saving machinery. An instructor may show to conviction that a greater outlay in stock, buildings, or some other fixed improvement would increase the productivity and the profits of a farm, but he carries no magic wand to raise the necessary capital.

CO-OPERATION.—Co-operation promises to help the small farmer to compete against the larger; to buy and sell for him and for another ninety-nine as if they were one; to banish him and his wife, his donkey and his dog from the marketplace for ever. If co-operation do so much it will do a great deal; but it cannot place the small farmer on the large farmer's level in the matter of machinery and the saving of labour; it will not keep his horse going while he is minding his cow. It must be remembered that while improvements benefit most those who adopt them first, they damage most those who adopt them last or never at all. In its early days, while the profits from the power loom were high, those from the hand loom remained as before; but when the pressure of increased production came on, while the power-loom weaver merely felt his profits declining, the hand-loom weaver was driven to the wall, excepting for very special purposes. Unless the small farmer can turn his farm to special purposes, his outlook is not brilliant.

IMPROVED TRANSIT.—But agriculture has been as deeply affected by other inventions as by those devised for its own benefit. When railways were built a farmer could deliver his grain as readily in London as in the nearest Billingham or Ditchington. Those supplying the towns beside them competed now not only with their neighbours but with other farmers at a distance. All were placed near the same level, so far at any rate as grain and other portable products were concerned. To meet the new conditions the policy of nearly every district had to be reconsidered and readjusted. Districts and farmers with special aptitude turned their attention to that they could best produce, often pressing hard upon others who had prospered so far upon the strength of their geographical position. Wheat-growing Essex had now to compete with Fife and Forfar, and even the northern shores of the Moray Firth.

OVERSEA COMPETITION.—But that was only the beginning, the first readjustment. Another had to be undertaken when the railway and the steamboat brought forward still more distant competitors, chiefly Anglo-Saxons in America and elsewhere, no less industrious and progressive than their relatives at home, with the result that no one dare predict the nature or the date of the final adjustment. These oversea competitors sent in grain, then bullocks, and these, having to be slaughtered on arrival, sometimes in great numbers, gave rise to cold storage. But cold storage on land suggests cold storage on sea, and now not only beef and mutton but even butter, eggs, poultry, and rabbits produced in New Zealand may be placed fresh upon any table in Britain.

RETURN TO PASTURE.—The readjustment has manifested itself chiefly in the return to pasture of many fields that once were tilled. Although pasture has increased in some parts through the increasing volume of imported feeding stuffs, the fields that have gone back are for the most part either so infertile or so difficult to till that they could

not compete as tillage land with better land beyond the seas. Yet much land is under pasture that could be tilled with profit. Good land under pasture is an economic waste. The contracting tillage area and the swelling volume of imported food give rise to different reflections in different minds. In these phenomena the rigid economist sees obvious prosperity while the prophet of race-decay sees absolute calamity. The economist sees a busy nation abandoning to others that in which they hold the advantage and concentrating itself upon more profitable occupations. The other extremist sees its food produced abroad and protected in transit by town-bred weaklings instead of Nelson and Wellington's bull-dogs. The economist's remedy is to improve the towns, the other's is "back to the land".

LAND NOT FULLY USED.—The land might be made to produce far more. Many pastures might be tilled and the productivity of the whole tillage area might be increased a third or even a half. But that will be done by more efficient farming, by adopting every possible improvement, and by the work becoming not only more profitable but more interesting. Even then, the land could employ more people than now, but the increase will consist of those who have never left it rather than of those who have gone back. It is even conceivable that, given sufficient warning and freedom to import manures, the United Kingdom could feed and clothe itself, but the sacrifice would be terrific.

PHILOSOPHICAL BIOLOGY

BY

J. BEARD, D.Sc.
University Lecturer in Comparative Embryology, Edinburgh

PHILOSOPHICAL BIOLOGY

CHAPTER I

DARWINISM

LAMARCK.—The problems of Philosophical Biology may be said to embrace the questions how the world of living things came to be what it is, and how these latter continue altered or unaltered from generation to generation. In bygone days there was more than one attempt made to conceive or to show how the various kinds of living things had arisen, how the most different forms of animals or plants were related together, and it had even been supposed that they might all have been produced the one from the other. The human imagination is, of course, unlimited in its range, and the difficulty always was not to suppose that such an evolution had taken place, but how it had happened. The great French naturalist Lamarck considered that animals were descended one from another, and that they had a common bond or union of blood-relationship. He attributed the evolution and change of species of animals chiefly to the effects of alterations in the conditions of life, that is, climate, food, &c., and to endeavours on the parts of animals themselves to improve their condition, this leading to modifications, which according to his views were inherited (inheritance of acquired characters). The sum of Lamarck's arguments was, that the direct influences of the environment induced changes in organization, which were directly handed on to the offspring, and that in this way there was an actual transmission of acquired characters. His views were not accepted, which, of course, does not in any way prove their falsity; and the general opinion still persisted that the different kinds of animals and plants, to which the term "species" had been applied, were immutable.

OKEN AND CHAMBERS.—The problem of "the origin of species" long remained unsolved, and appeared to be insoluble. Oken thought that animals had arisen from a primeval slime, and views of the possibility or probability of the occurrence of spontaneous generation had been advanced. Even to-day such ideas are not extinct. In the *Vestiges of Creation* Robert Chambers endeavoured to trace the action of general laws throughout the universe, and to demonstrate that animals and plants had arisen in

orderly succession under the conjoint action of external conditions and unknown laws of development.

HERBERT SPENCER.—As Mr. Wallace puts it: "The great majority of naturalists, and almost without exception the whole literary and scientific world, held firmly to the belief that species were realities, and had not been derived from other species by any process accessible to us; the different species of crow and of violet were believed to have been always as distinct and separate as they are now, and to have originated by some totally unknown process so far removed from ordinary reproduction that it was usually spoken of as 'special creation'." The 'development hypothesis', or that of evolution, prior to the Darwinian period, was supported by Herbert Spencer in his essay in the *Leader* (1852). According to him, it could at that time be shown that the process of modification had effected, and was effecting, great changes in all organisms subject to modifying influences. "The supporters of the development hypothesis can show that any existing species, animal or vegetable, when placed under conditions different from its previous ones, immediately begins to undergo certain changes of structure fitting it for the new conditions. They can show that in successive generations these changes continue, until ultimately the new conditions become the natural ones, and so on." As evidenced by this essay, Spencer, like others before him, fully recognized the existence and the facts of transition, of its being due to natural influences and causes always acting, and to adaptation to environment. No attempt was made to account for the existence of variation or to explain how the conditions acted in bringing about changes in animals or plants.

DARWIN AND WALLACE.—Such was the state of matters when in 1858 the views of Charles Darwin and Alfred Wallace, independently arrived at, were published simultaneously. Considerations of space forbid any reference to the historical facts attending this publication. They will be found fully detailed in *The Life and Letters of Charles Darwin*, written by his son. Both observers postulated the fact that variation does occur, and, indeed, the first two chapters of Darwin's *Origin of Species* are taken up by accounts of variation under domestication and under nature. To Darwin and Wallace it was clear that variations did occur in both plants and animals. They did not attempt to account for or explain these variations. Indeed, not until much later did it really come to be recognized that the occurrences of variations themselves were problems to be cleared up. If offspring resemble their parents, yet tend to vary from them, then, as we shall see later on, the reasons for the resemblances and the differences need to be searched after.

The Darwinian theory, founded by Darwin and Wallace, must not be confounded with the doctrine of evolution or progressive development. It is, in fact, an attempt to explain how the latter has come to pass, to reveal the "mechanism" by which progressive change has constantly been effected. Starting from the occurrence of variation in nature, they pointed out that the number of offspring produced was, as a rule, far greater than the number which could survive and attain maturity. Owing to this there was a constant "struggle for existence" going on, under which the weaker

individuals and the weaker forms in general were exterminated. This resulted in a "natural selection" of those best fitted for the actual conditions of life, in a "survival of the fittest".

ARTIFICIAL SELECTION.—Owing to the difficulties encountered at all times in observing the actual facts in animals or plants in the wild state, the phenomena and the results of artificial selection, as practised by man, have been made use of as supports of the theories advanced. Nature, like the breeder, makes use of varieties to produce new effects. In artificial selection nothing new can be obtained except by the careful and patient selection of something already in existence. A small observable difference or variation often suffices for a start. It may be some peculiarity of coloration, something in the arrangment of feathers, a greater or less length of some structure, such as the leg, and so on. By choosing carefully such chance individual variations, and crossing the forms possessing them, it is often found that some or other of the offspring present these characters in a more marked degree than the parents. Whatever else be then done, whether they be exterminated or not, those individuals which do not possess the characters which it is desired to accentuate, or possess them only in a less degree, are excluded from the further breeding experiments. These latter are continued in this rigorous fashion from generation to generation.

By this artificial selection of animals and plants for breeding purposes man is often able to produce new varieties, differing to a remarkable degree from the original parent forms from which the breeding experiments started. Many of our choicest garden flowers, as well as many varieties of domesticated animals, many sorts of poultry, pigeons, &c., have arisen in this way, and the process is constantly being set in operation anew. To take a concrete instance, the manifold varieties of pigeons, the jacobin with its hood, the pouter, the tumbler, the carrier, the turbit, the trumpeter, and the fantail have all been produced by man through the action of artificial selection (fig. 425). All these varieties differ in marked respects from the parent stock, the rock pigeon, from which, in fact, all have been derived by artificial selection. Among plants all the garden roses, such as the hybrid teas and hybrid perpetuals, including such examples as *Maréchal Niel* and *Gloire de Dijon*, all the American tree carnations, such as *Mrs. Lawson*, *Enchantress*, &c., and the wonderful variety of chrysanthemums—all these and many more are instances of artificial selection as practised by man.

Such *artificial varieties*, as they may be named in contrast to the *natural varieties* occurring in nature, can sometimes be "fixed", as the breeder terms it, and then they breed true, that is, the artificial variety breeds true within itself. Often again, as in many plants, for example, this is impossible, and they do not "come true to seed". To continue them in plants recourse must be had to cuttings, buds, &c. Thus there has never been but one scarlet geranium, *Henry Jacoby*, never more than one rose tree, *Gloire de Dijon*. By asexual reproduction all existing forms of these inconstant varieties owe their origin to one original parent stock. The analogy of artificial selection is used by Darwin and Wallace to explain the action of natural selection. It is supposed that in nature there are

causes acting in ways similar to the actions of man when he selects artificially the best animals for breeding purposes, and that these causes must lead to new departures in structure. The tendency of animals and plants to increase rapidly in number is insisted upon. A good instance is the rapid multiplication of rabbits in certain parts of Australia. In many

Fig. 425.—Blue Rock and some of the Domesticated Varieties of Pigeon

1, Blue rock (*Columba livia*); 2, Tumbler; 3, Owl; 4, Jacobin; 5, Fantail; 6, Pouter.

places these have driven out or exterminated the native herbivorous pouched animals or marsupials.[1]

There are natural causes which tend to keep the numbers stationary, and the effect of the removal of any check to increase is dilated upon. With such an increase there ensues a struggle for existence, and this

[1] Natural selection is sometimes given the credit of this, but rabbits crop the herbage so closely that no other herbivorous animal can follow them.

applies to all animals at all times, the competition being keenest among the most closely similar forms. Natural selection is thus the keynote of the Darwinian theory. But it must be noted, that the fittest to survive are not necessarily the most ideally perfect. While artificial selection is directed solely towards the benefit or the pleasure of man, natural selection acts for the good of the species. Artificial selection may be said to be carried out independently of the environment, and it often results in varieties, as will be seen, which are not really adapted to the environment. In natural selection, as first enunciated by Darwin, little or no stress was laid upon the environment or its influence, but there can be no question that the species and varieties which have a survival value are such as are adapted to the particular environment under which they came into being. Indeed, a natural variety may be defined as one adapted to the environment.

DIFFICULTIES AND OBJECTIONS.—At various times, and by an array of naturalists and critics, difficulties and objections regarding the theory of natural selection have been raised. These have been met in various ways, some of them by Darwin and Wallace, others by other advocates of the "Darwinian Theory". One of the earliest was as to the smallness of the variations, another as to the probabilities of the right variations occurring when required. The beginnings of important organs, such as the milk glands of mammals, and the curious features connected with the asymmetry and the eyes of flat-fishes, as well as the origin of the eye itself, were urged, and answers more or less adequate given. The effects of isolation, whether on an island, or in a valley shut in by mountains, were insisted upon by Gulick.

THE SWAMPING EFFECTS OF INTERCROSSING.—A supposed insuperable difficulty was advanced as long ago as 1867, and Darwin acknowledged that it proved to him that "single varieties", which are usually termed "sports", could very rarely if ever be perpetuated in a state of nature, as he had at one time thought might be the case. It has been argued, especially by G. J. Romanes, that the same variation does not occur simultaneously in a number of individuals inhabiting the same area, and that it is a mere assumption to say that it does. It has been admitted that if the assumption were granted the difficulty would end, for given a sufficient number of individuals varying in the like direction and manner, there need be no longer any danger of the variety becoming swamped by intercrossing. Later on the well-known ornithologist, Mr. Seebohm, stated that the supposed swamping effects of intercrossing were "unquestionably a very grave difficulty, to my mind an absolutely fatal one to the theory of accidental variation".

Postulating the occurrence of variation in nature, and making no attempt to unravel the causes underlying such variations, to wit, the attempts on the parts of all living things to adapt themselves to their environment, the advocates of natural selection have never been able to overcome this objection. While it is fatal to the theory of natural selection, at a later stage it will be seen that, under other views, the objection vanishes, for there can be no swamping effects of intercrossing with char-

acters suited to a particular environment, as it is inconceivable that any of these should be eliminated in the germ as long as they are useful.

NEO-LAMARCKISM.—While the Darwinian theory has found its strongest support in Europe, especially in Great Britain and Germany, the views of Lamarck have been advocated vigorously in America, especially by Cope and Osborn. Cope's conclusions were founded especially on the study of the mammalia as revealed by the fossils unearthed by his researches, while Osborn's work on the ancestral history of the teeth of the higher animals, leading him to evolve the complicated features of the mammalian dentition from a simpler three-coned (tritubercular) form of tooth, have carried him in the same direction (fig. 426). The alterations and complications, which have taken place upon the original tritubercular type of tooth, are considered as having been acquired by the individuals in adaptation to the feed-

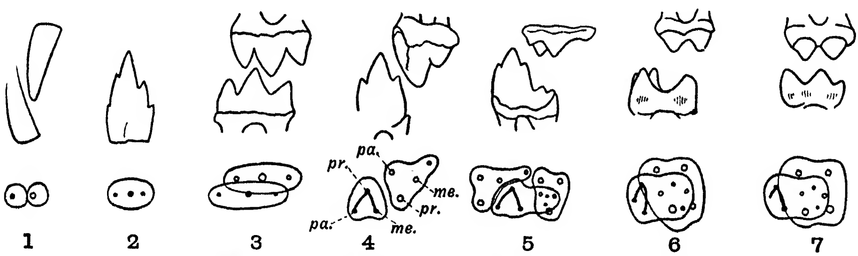

Fig. 426.—Tritubercular Theory of Cusp-development in the Teeth of Mammals. (From Cope, after Osborn.)

1, Reptilian stage; 2 and 3, triconodont stages; 4, first tritubercular stage; 5 and 6, stages of development of heels, leading to 7, upper molar with four cusps, lower molar with five cusps.

ing and mode of life, and to have been handed on by an "inheritance of acquired characters".

WEISMANN.—It may be said that at the death of Darwin in 1882 the Darwinian theory of natural selection had not overcome all the possible difficulties and objections, and this was recognized, perhaps, by none more clearly than by one of its foremost advocates, Weismann. Some of his most important investigations, out of a long series going back now nearly half a century, began about this time, and with them there commenced a new epoch in the history of evolution. To his work, perhaps more than to that of any other observer, has been due the attempt to elucidate the phenomena of evolution, and to advance knowledge in the light of the Darwinian theory by considerations drawn from heredity, and their bearings upon selection, variation, protective mimicry, the cessation of natural selection (panmixia), and so on.

CHAPTER II

HEREDITY—GALTON AND WEISMANN

HEREDITY.—With the introduction of embryology and its findings into the discussion of Darwinian problems new aspects were given to these. Hæckel and earlier writers, by using the hypothesis of a recapitulation in development, under which each and every individual in the course of its development "climbed its own genealogical tree", had endeavoured to furnish a developmental basis for the conclusions of Darwin and Wallace. The recapitulation theory, as it has been termed, has often been ascribed to Carl Ernst von Baer, one of its most strenuous opponents, but historically it can be traced to Oken, if not to Kielmeyer. In the early years of the nineteenth century Oken was its most prominent exponent. Although this doctrine of recapitulation in development has always been advocated by Weismann, and although it still has many adherents, there are not wanting embryologists who regard it as destitute of any real foundation in the facts of animal development.

Prior to the last twenty-five years embryology played no real part in the discussions of the Darwinian theory. As little can it be said to have influenced the views held as to heredity. Any clear conception as to the "how" of germinal continuity from generation to generation, any attempt by direct observation to explain from embryological facts and findings how it comes about that offspring resemble their parents while at the same time differing from them (genetic variation), dates not much farther back than twenty-five years. Any worker whose record covers that span of time has seen the gradual growth of scientific views of heredity based on embryological research, and has had the opportunity of watching the closer and closer approach of this field of work towards the region so long associated with the names of Darwin, Wallace, Lamarck, and others.

The problem of heredity is almost the greatest one in embryological science. There is a greater, the nature of life itself; but in all probability this, considered as a problem of science, is insoluble. Heredity and its problems have occupied a prominent position in the discussions of recent years. The progress of research into the life-history of the cell, the structure and functions of the cell-nucleus, the phenomena of cell-division, more especially those attending the "ripening" of the sexual products, eggs and sperms, have naturally played important parts in these. So much so has this been the case that a distinguished naturalist, H. F. Osborn, might well utter the prophetic words "the study of heredity will ultimately centre around the structure and functions of the germ cells". These words, indeed, indicate the crucial point on which all theories of heredity depend, the nature, origin, history, and properties of the germ-cells. The historian of heredity must recognize that the views held concerning this depended primarily on those accepted concerning the origin of the germ-cells and their history. For long years, in fact until comparatively recently, the germ-cells were regarded as nothing more than special portions of the

individual body containing them. We still speak of the "sexual organs", ovaries or testes, of the individual, as though these were essential parts of its economy, necessary to its own life, like a stomach or liver, lungs or kidneys. Under such conceptions of germ-cells they could arise from almost any cells of the body, as still maintained by some, more especially by medical writers. Under such views "the embryo" or individual might be regarded as "a chip of the old block", the germ might be said to be, in the words of Huxley, "simply a detached living portion of the substance of a pre-existing living body". This was a very simple way of accounting for the *resemblances* between parent and offspring.

Previous views as to heredity and germinal continuity, popular and scientific, acquired new aspects in the light of Francis Galton's theory of the *stirp* (1875). This was conceived of, the author not being a practical embryologist, as something left over from every development, a material basis from which ultimately the next generation took its origin. In the conception of this "stirp" we have for the first time a recognition, dim and indistinct though it be, of a tangible something connected in some way with the germ-cells, out of which the phenomena of heredity proceeded.

GALTON'S LAW.—Mr. Francis Galton, the enunciator of the foregoing theory, from researches and data as to the stature and other qualities in man, and as to the coat colour in Basset hounds, was led to formulate a law of inheritance. According to this law the two parents between them contribute on the average one-half of each inherited faculty, each of them contributing one-quarter of it. The four grandparents contribute one-quarter, or each of them one-sixteenth, and so on; the sum of the series—$\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} +$ &c., being equal to 1, as it should be. It is a property of this infinite series that each term is equal to the sum of all those that follow, thus: $\frac{1}{2} = \frac{1}{4} + \frac{1}{8} + \frac{1}{16} +$ &c.; $\frac{1}{4} = \frac{1}{8} + \frac{1}{16} +$ &c., and so on. The prepotencies or subpotencies of particular ancestors, in any given pedigree, are eliminated by a law that deals only with average contributions, and the varying prepotencies of sex in respect to different qualities are also presumably eliminated. It should be noted that, as the sum-total of all the inherited faculties, qualities, or characters, under this law, equals a unit in both embryo and in its germ-cells, it is not easy to conceive how there can be any latent qualities which might suddenly reappear in some succeeding generation. Of this supposed law of heredity it has been said by Karl Pearson that "the law of ancestral heredity is likely to become one of the most brilliant of Mr. Galton's discoveries; it is highly probable that it is the simple descriptive statement which brings into a single focus all the complex lines of hereditary influence. If Darwinian evolution be natural selection combined with heredity, then the single statement which embraces the whole field of heredity must prove almost as epoch-making to the biologist as the law of gravitation to the astronomer."

The later developments of Mr. Galton's work, this law of ancestral inheritance, and the study of "Biometry" have culminated in attempts to found a science of "Eugenics" for the purpose of improving the human race. As all such studies tend to reveal nothing of the causes of variation, as they deal with somatic variations as a rule, and fail to distinguish such

sharply from genetic ones, which alone are inherited, and as they ignore the environment and its influences, it is difficult to perceive what improvement in man the study of "Eugenics" can effect. Eugenics may have a future as a branch of mathematics, but how shall it become an integral portion of biology, the science of living things?

WEISMANN'S THEORY OF THE GERM-PLASM.—A large space in the history of heredity and of the Darwinian theory is occupied by Weismann's researches. By argument and by laborious experiments he has long opposed the leading tenet of the Lamarckians, the inheritance of acquired characters. Indeed, although Weismann did not demonstrate that there is nothing at all handed on, and that therefore there can be no inheritance of acquired characters, he showed the falsity of this doctrine. His researches into the possible mode of germinal continuity, culminating in his theory of the germ-plasm, extend back over more than twenty-five years. The starting-point may be taken to have been in 1883, when in a public lecture he first distinguished between two kinds of substances in cells, termed by him somatoplasm and germ-plasm. In this conclusion Galton's theory of the stirp begins to acquire a more definite form. Somatoplasm is the ordinary substance of which the body-cells or "soma" may be said to be composed, and it has no reproductive powers or qualities, which would enable it to give rise to a new individual of the species. The germ-plasm, on the other hand, is a peculiar substance, which is restricted to the germ-cells, and as a rule is not present in somatic or body-cells. In the germ-cells both somatoplasm and germ-plasm are united, and this accounts for the fact that such cells possess not only the potentialities of building-up a soma or body anew, but that they can provide for the continuation of the species. Inheritance, therefore, depends upon the continuity of the germ-plasm from generation to generation (fig. 427). This was only the beginning of Weismann's theory of the germ-plasm. Since then it has been elaborated again and again by its author. The germ-plasm is a hypothetical substance, and it remains hypothetical to this day. It can only be recognized by its deeds in certain cells, these deeds stamping such cells as germ-cells. In 1892 he writes of the germ-plasm that "this substance can never be formed anew; it can only

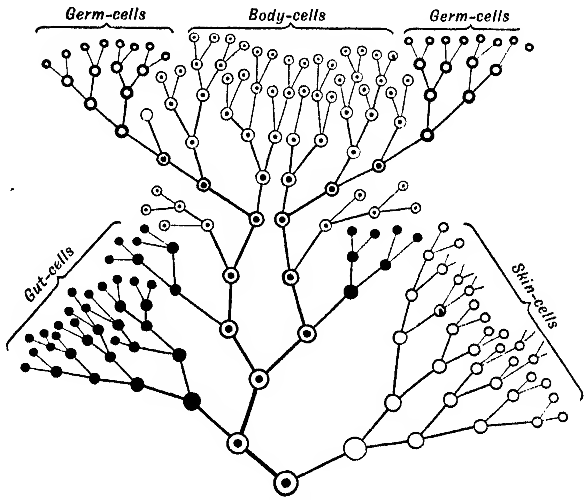

Fig. 427.—Diagram of the Germ-track of a Round Worm (*Rhabditis*), according to Weismann (After Weismann.) The various circular markings indicate cells, starting from the fertilized egg at the foot.

grow, multiply, and be transmitted from one generation to another. My theory, therefore, might well be denominated 'blastogenesis'—or origin from a germ-plasm, in contradistinction to Darwin's theory of 'pangenesis' —or origin from all parts of the body." From this time onwards until to-day the recognition of a special somatoplasm disappears from Weismann's writings, its last use being when it was employed by him to elucidate the meaning of the formation of the first polar body of the egg, some twenty years ago, as the separation of germ-plasm and somatoplasm. Again, in 1892 he writes: "The difference between the body (soma) in the narrower sense and the reproductive cells"—is—"that the germ-cells alone transmit the reproductive substance or germ-plasm in uninterrupted success. n from one generation to the next, while the body (soma) which bears and nourishes the germ-cells is, in a certain sense, only an outgrowth from one of them". In his book on the *Germ-plasm* (1892) Weismann furnished the first elaboration of his doctrines, and applied these in detail to natural selection, as well as to other zoological problems. He stated that this hereditary substance or germ-plasm was identical with the chromatin of the nucleus of the cell.[1]

THE NATURE AND BUILD OF THE GERM-PLASM.—The ultimate constituents of the germ-plasm are the *biophores*, each of these being a group of molecules, on which the phenomena of life depend. They correspond to Herbert Spencer's "physiological units". These biophores, the number of possible kinds of which is unlimited, constitute all protoplasm, and "each kind corresponds to a different part of a cell". They are grouped together to form *determinants*, which are the entities deciding the nature of any particular kind of cell, any particular structural character or function. In the cell-nucleus of a cell containing germ-plasm the determinants are grouped together to form *ids*, and, lastly, the chromosomes of the nucleus are identified with other groups of ids, and are spoken of as *idants*. The latter can, of course, be recognized under the microscope, and since they can in some cases be still further resolved into granules, it is possible that the ids are visually recognizable. The determinants and the biophores are ultra-microscopic. To all these entities unlimited powers of increase by division are postulated. The cause of each determinant reaching its proper place in the developing body depends on the fact that it takes up a definite position in the id of the germ-plasm. "Each id in every stage has its definitely inherited architecture; its structure is a complex but perfectly definite one, which, originating in the id of germ-plasm, is transferred by regular changes to the subsequent idic stages. The structure exhibited in all these stages (of development) exists potentially in the architecture of the id of germ-plasm: to this architecture is due, not only the regular distribution of determinants, that is to say, the entire construction of the body" from start to finish, "but also the fact that the determinant of a small spot on a butterfly's wing, for example, reaches exactly the right place"; or again, that the determinant of a

[1] There appears to be a curious contradiction here. Ordinary somatic cells contain no germ-plasm, according to Weismann, but their nuclei do contain chromatin. In some cells (germ-cells) this chromatin is germ-plasm, in somatic cells it is not.

segment of a leg of a fly reaches this particular spot. Every independently variable and heritable character is represented in the germ-plasm by a determinant. As each idant or chromosome is made up of a full set of ids, determinants, and biophores, it follows, under Weismann's views, that

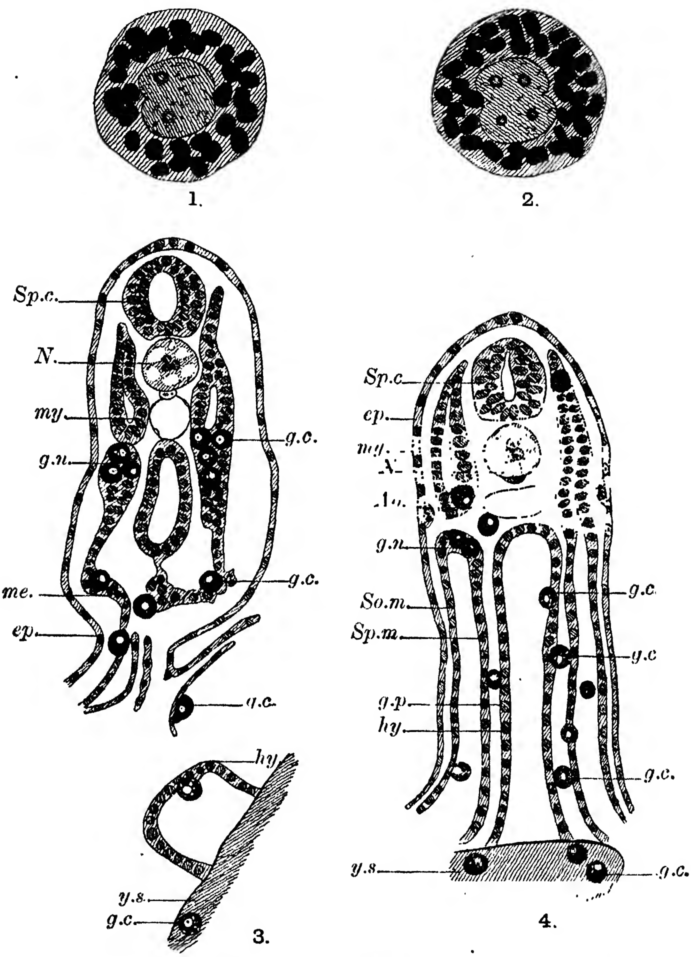

Fig. 428.—To illustrate the germ-cells and their wanderings as seen in developing fishes. The two figures on the right side are of *Pristiurus*, those on the left of the skate, *Raja batis*. 1 and 2 are germ-cells highly magnified; 3 and 4 are transverse sections in the region where embryo and yolk-sac are connected. Both figures show germ-cells in the yolk below, and higher up in migration into the embryo.

in the nucleus of any germ-cell there will be as many full sets of these present as there are chromosomes.

The mode of reproduction of the higher animals is the biparental (bisexual) one, where one germ-cell, the sperm, unites with another germ-cell, the egg. Each of these, as is generally recognized by embryologists, contains within itself all the potentialities of forming or unfolding a new individual of the species. As under Weismann's views each chromosome of egg or sperm contains a full set of ids, determinants, &c., in fertilization

or "amphimixia", which is the mingling of two different sets of germ-plasm, there are united together different ancestral germ-plasms derived from two different sources.

In the development of the fertilized egg it is its composition, due to the union of two germ-cells derived from different ancestral sources, which determines everything in the organization and constitution of the resulting individual. In the course of the development the ids or groups of characters are separated out, and this separation proceeds down to the determinants, which, as we have seen, decide the nature and structure of any particular character, a feather, a scale, or some portion of a finger, for example. No details of this process can be observed, beyond the broad features, which have been recognized since in 1827 Carl Ernst von Baer first stated that development was a progress "from the general to the special". But we are not concerned here with the more detailed application of Weismann's views on the germ-plasm to the development, the upbuilding or the unfolding of the parts of the embryo. It may be noted that Weismann, like a few other embryologists, rejects as an impossibility the generally accepted theory of *epigenesis*, or the gradual adding of part to part. He advocates the theory of unfolding, which differs from the ancient evolution-theories of Haller, Bonnet, and others in this way, that whilst they held a theory of evolution or unfolding with preformation, Weismann maintains, rightly in our opinion, an evolution with *predestination.*

Germinal Continuity.—How then does Weismann's theory of the germ-plasm account for germinal continuity from generation to generation? How does it explain variation? He has always rejected an actual continuity of germ-cells from generation to generation. The early origin of germ-cells in a few cases has been common knowledge for a long time. But from these or some later cases none ever dreamt of setting up a new conception of the development of the higher animals, or of advocating an actual continuity of germ-cells from generation to generation. If the germ-cells be not somatic in origin, that is, not parts of the individual body, the mode of development cannot be that assumed—without proof—by investigators for the past hundred years and longer. As for an actual continuity, the most that any zoologist every ventured is, indeed, represented in the following words of Weismann, written in his latest work: "Could we assume that the egg on commencing development at once divided into two cells, of which the one gave rise to the entire body (soma), while from the other only the germ-cells contained within this arose, the matter would be theoretically very simple; we should say that the germ-plasm of the egg doubled itself, as happens to the nuclear substance in every cell-division, and that this divided into two equal halves", one of which formed the body of the individual, whilst the remainder, its germ-plasm remaining latent, only manifested activities sufficient to give rise to and to impress its stamp upon certain cells, its products, which became the germ-cells. This, according to Weismann, had only proved to be the case in some insects. But even here there is not a division of the egg into two halves, somatic and germinal respectively

in destination. In fact, nowhere, so far as is known, does the ancestral or primitive germ-cell arise as early as the first division. It is merely a euphemism to speak of its origin "after the first couple of divisions", the number of divisions prior to the appearance of the ancestral germ-cell being from four to ten. Weismann's own researches on the hydroid polypes, published in 1883, have been held to prove a somatic origin of germ-cells, but in the light of more recent knowledge they are seen to establish what is found to happen in higher animals also, an origin (pre-embryonic) of germ-cells in an asexual stock, and their subsequent migrations into the embryo or individual.

It has been assumed to be the task of the fertilized egg to give rise straightway to a new embryo, and the hydroid polype has been regarded as comparable to the "embryo" or individual of any one of the higher animals. It has been ignored that the first product of the early divisions of the egg is always an asexual form or foundation. Regarding the hydroid polypes, it has not been clearly recognized that, in origin, mode of growth, and other peculiarities, the polype corresponds to the sporophyte or asexual generation of plants (the flowering plant), that it is not the bearer of sexual products, and it has been believed, wrongly, that the medusa and the hydroid polype, upon which it arises, are practically the same (homologous).

When the division or cleavage of the egg is really finished, there are no somatic cells present, but plenty of germ-cells. It does not suffice to study the first appearance of germ-cells in the embryonic body—by so doing their somatic origin may be concluded, whereas they exist prior to the appearance of any trace of a soma. To trace the whole chain of continuity, to reach the conception of an actual continuity of germ-cells, an adequate picture must be formed of all that happens to the products of the egg from the moment of fertilization until the appearance of a new egg. In fact, the whole course of the life-cycle must be revealed. Weismann has denied an actual continuity, "because as a matter of fact the sexual cells of all plants and those of most animals do not separate themselves from the beginning from the somatic cells".

This is just the question at issue! The statement contains two fallacies, which rob it of all force. Probably all the higher plants or Metaphyta are referred to, for in some of the lower ones all the cells might be regarded as potentially reproductive. In the higher plants they do appear at a very early period in the sexual generation. The higher one ascends, the earlier is this epoch; for in the flowering plants, for instance, the life-span of the sexual generation or gametophyte is exceedingly short, and it is concerned solely with the differentiation of, and the provision for, the germ-cells. Were they to appear in the sporophyte, or flowering plant, it would lose this character, and become a sexual generation. Even in the asexual generation the continuity is unbroken, for in this the future germ-cells are represented by their direct ancestors, the one or more cells forming the apex. Regarding animals, the point insisted upon is the early appearance of germ-cells in the sexual generation, in the embryo. In drawing parallels between plants and animals the conditions in the corresponding generations

in the two kingdoms must be compared, sexual generation with sexual generation, asexual with asexual.

Even now the early history of germ-cells of "most animals" has as yet been investigated very inadequately. Where it has been traced back to the farthest possible point, there invariably a very early origin has been made out. There is really no reliable evidence pointing to a late appearance of the germ-cells in any single case.

AMPHIMIXIA.—The term *amphimixia*, to denote the mingling of two germ-plasms, was introduced by Weismann some years ago. In some parts of his latest work it is still used in this sense. According to him the hereditary tendencies of two individuals are united (by the junction of egg and sperm) together, "and the organism, whose formation is derived from this mixed germ-plasm, must, therefore, take on characters from both parental individuals, in a sense be made up of traits of both parents". This is one result of amphimixia, whilst the other, brought about by the complicated machinery of the reducing division, which results in new combinations of the "ids" or groups of characters, is the preservation of individual differences by means of the continually fresh combinations of characters already present in the species. In this way all the phenomena embraced by Weismann in the conception of amphimixia become a cause of variation, but, in his words, "not the real root of variation itself". As will appear later, the actual cause of variation is referred by Weismann to certain complicated phenomena, termed by him "germinal selection".

The term "amphimixia" is undoubtedly a convenient one, and it would be still more useful were its meaning not conditioned to so great a degree by hypotheses relating to the "reducing division". Even though the existence of a germ-plasm were admitted, the known facts do not point to the union of egg and sperm as the mingling of two such germ-plasms, or as a mixing of two individualities. Owing to the nuclear duplication, observable from the time of fertilization to much later periods of the cycle, fertilization is not in any sense the mingling of two germ-plasms, or even of two lines of ancestry, but it is merely the joining together of two (potential) sets of characters, of two individualities. Nor is it clear that the subsequently formed offspring must therefore take on characters from both parents, for known facts go to show that it might be made up almost or even entirely of characters belonging to the line of one parent only, or apparently even of neither. Moreover, the Mendelian results cannot be brought into line with this view of the rôle of amphimixia.

The foregoing definition of amphimixia, given in Weismann's earlier writings, receives further additions in his more recent work, where he writes: "To-day amphimixia in the entire world of organisms, from the unicellular ones to the highest plants and animals, has the meaning of an increase in the capacity for adaptation of organisms to their surroundings, in that by it the simultaneous harmonic adaptation of many parts is possible. It accomplishes this by the continual new combination of the germ-plasm ids of different individuals, and thus furnishes the processes of selection with the means of fostering the favourable ones, and of eliminating the unfavourable tendencies to variation, as well as the collection and union

of all the variations necessary for the proper further development of a species. This indirect action of amphimixia upon the preservation and transformation powers of living forms is the chief reason of its general introduction and retention in the whole known kingdom of organisms from the unicellular ones upwards."

A clear conception should be formed of all that Weismann includes under amphimixia. The new combinations of chromosomes or groups of characters, which under his views happen at the reducing division—the last of the two assumed universally for all the higher animals, and which precedes the actual formation of gametes—lead to what might almost be described as an infinite, certainly a very great, variety of gametes, and this would of necessity be such that of the four sperms formed by a spermatocyte no two could be alike in their characters. Indeed, if this be correct, it is not the differences among the progeny of any two parents which require explanation—the phenomena of the reduction amply accounting for these—but the resemblances to one another and to their parents. It is therefore, under Weismann's views, the initial differences in the gametes which in the new combinations of the germ-plasm ids really furnish such abundant material for the continued action of germinal selection in his sense, the mingling of the qualities of the germ-plasms of the two gametes determining the organism.

In the cell researches of the past thirty years, especially in those treating of the "ripening" of the germ cells, Weismann's theories have had much influence. His views as to the import of the two divisions leading to the formation of the polar bodies of the egg, for example, as is natural, have not always been the same. It is no part of our business here to deal with any earlier interpretation now abandoned. What we have to do with is the significance assigned to the observations on the ripening and reducing divisions leading to the formation of eggs and sperms. Even before there were any observations pointing to this, Weismann had surmised a kind of conjugation between different chromosomes in the germ-cells prior to or during the ripening process. This was verified by some observers, disputed by others. It is not a thing which can actually be observed under the microscope; it can only be inferred from the appearances seen in permanent preparations. The conjugating chromosomes or idants are supposed to be respectively paternal and maternal in origin. In one or other of these two final divisions these are supposed to be separated into different products, so that in this way the four sperms, for example, would contain different ancestral plasms. In this way a considerable amount of variety among the gametes, eggs, and sperms would arise at the reduction of chromosomes, in some of these certain ancestral germ-plasms would be eliminated, in others again these would be retained.

GERMINAL SELECTION.—Whilst he has urged the "all-sufficiency" of natural selection against Herbert Spencer, Weismann has re-enforced it very considerably by the conception of a germinal selection. It is difficult in the absence of any authoritative definition of the process to describe what Weismann means by germinal selection. It is purely a mental concept, and it is not brought into definite connection with any known epoch or

phenomenon of the development. Underlying it is the assumption that the determinants, those entities which decide the characters of every part of the organism, must be contained several times or many times within it; while, on the other hand, every id made up of determinants contains potentially the whole body. The child is, therefore, not determined by the determinants of one id, but by those of many ids, and the variations of any part of the body depend not on the alteration of a single determinant x but on the combined workings of all the determinants x's as they are contained in the total ids of the particular germ-plasm. The prime cause of the individual variation is set down to passive accidental oscillations in nutrition. Most remarkable of all, he writes, that germinal selection is quite independent of the environment. In this respect Weismann differs from Ewart, who recognizes not only a germinal variation but an environmental one.

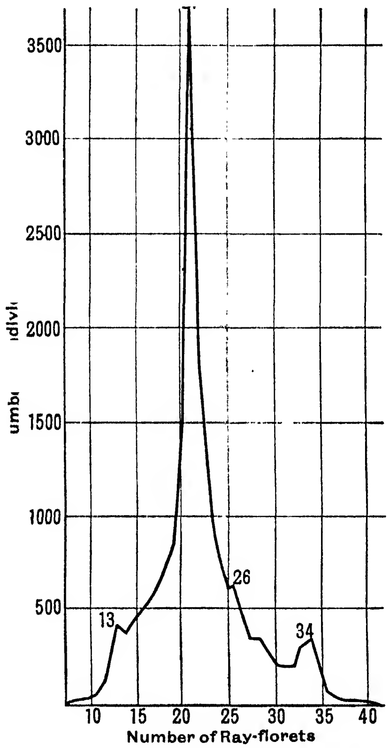

Fig. 429.—To Illustrate by a Curve the Variations in the Number of Ray-florets in the Ox-eye Daisy. (After Vernon.)

BIOMETRY.—In recent years, under the leadership of Galton, Karl Pearson, and Weldon, a line of research into the problems of heredity and variation, known as "biometry", has come into existence. This study involves close measurements and mathematical calculations regarding the range of variation in an extensive series of individuals of some variety. On comparing together a great number of individuals of any species or variety, they are found to present differences from one another in size, shape, colour, relation of parts, &c., and indeed no two of them may be alike. By measuring an extensive series of these variations, then plotting them out to scale on paper, a curve of variation is formed (fig. 429). Some point in this curve will be occupied by the average mean, and on each side of it will be grouped other variations from the mean, according as they are greater or less. It is found by observation that in any given case the variations of the majority of the characteristics of various organisms are distributed about their mean in accordance with the law of error. In order to obtain an index of the variability of any characteristic, some method of determining the degree of spread of its curve must be adopted, and one of the methods widely employed is to determine the so-called probable error. It is impossible in the space at disposal to give a real conception of the methods involved in this branch of research. It brings the use of mathematical measurements and calculations into the domain of natural

science. A further extension has been the creation of a study of "Eugenics", with a view to the possible improvement of the human breed under the existing conditions of law and sentiment.

QUÉTELET'S LAW.—The study of fluctuating or individual variability is now chiefly carried on by these mathematical methods. Such a treatment of the facts is undoubtedly of value. The law of Quételet, to which the facts conform, is simple. It claims that for biological phenomena the deviations from the average comply with the same laws as those from the average in any other case, if ruled by chance only. This fluctuating variability is an almost universal phenomenon. Every organ and every quality may exhibit it. It is divisible into individual and partial fluctuation, the first being differences between individuals, the second deviation shown by the parts. These fluctuations take place in two directions, being either increase or decrease. It is important to note that they are limited to what

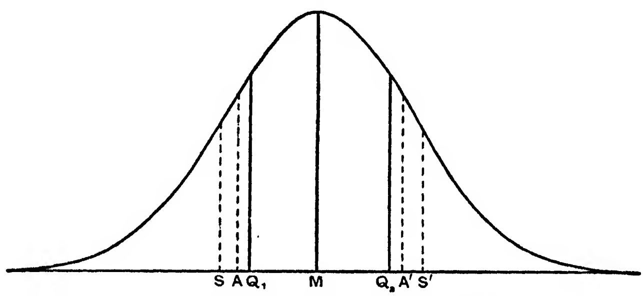

Fig. 430.—Normal Curve of Error, to illustrate Quételet's Law

is available. They may produce long or short forms, but never a race of giants or dwarfs. As Bateson has insisted, no amount of selection among tall peas will ever result in a dwarf race, or vice versa. According to de Vries, nourishment is the potent factor.

A ready demonstration of Quételet's law is given by the placing of a sufficient number of adult men in a row arranged according to their size. The line passing over their heads proves to be identical with that given by the law of probability.

With curves of variation a real standard is afforded by the steepness of the slope of the curve. It may be unequal on its two sides, and it may differ for different cases. The steepness is usually measured by means of a point on the half-curve, and for this purpose a point is chosen lying between the average and the extreme. It is the point on the curve which is surpassed by half the number and not reached by the other (distal) half. This point corresponds to the value called the "probable error", and is termed by Galton the *quartile*, for it is evident that the average and the two quartiles divide the whole observations into four equal parts (fig. 430). The whole curve is defined by the average and the quartiles, and the result of hundreds of measurements or countings may be summed up in three, or in symmetrical curves two, figures. The quartiles are important for comparing different curves together. If the curves overlap, then the

variations are the same. A consideration of cases of complicated curves with two or more summits would carry the discussion too far.

CHAPTER III

VARIATION—MENDELISM

MENDELISM.—This has sometimes been termed the experimental study of heredity. The original discoveries, upon which this study has been based, were published by the Abbot of Brünn, Gregor Mendel, in 1866. His results were ignored until the beginning of the present century, but in the past few years the study has made immense progress, and an extensive literature has arisen around it. For the purposes of his experiments on the results of intercrossing, sometimes but erroneously spoken of as "hybridization", Mendel chose plants. He sought for a plant with distinct races, possessing differentiating characters, and one in which the influences of foreign pollination could be excluded. The pea, *Pisum sativum*, fulfilled these conditions. The flowers are self-fertilized, and pollination by insects is very rare. For the purposes of the experiments seven pairs of characters were selected. These were: (1) shape of ripe seed, round, or angular and wrinkled; (2) colour of endosperm (cotyledons or seed-leaves), yellow, or green; (3) colour of seed-skin, grey or grey-brown, or white; (4) shape of seed-pod, simply inflated, or deeply constricted between the seeds; (5) colour of unripe pod, a shade of green, or bright yellow; (6) nature of inflorescence, whether the flowers were arranged along the axis of the plant, or terminal; and (7) length of stem, tall (6 to 7 ft.), or dwarf ($\frac{3}{4}$ to $1\frac{1}{2}$ ft.).

The peas were crossed first of all with respect to any two of such corresponding characters; thus the pistils of the flowers of the yellow-seeded peas were pollinated from the anthers of green-seeded peas, and vice versa. The offspring of the cross, the seeds in this case, exhibited the character of *one* of the parents in almost undiminished intensity, and there were no intermediates. One character of any two prevails to the exclusion of the other in the cross, and this is termed *dominant*, the other being *recessive*. In the next generation obtained from such seed the cross-breds were allowed to fertilize themselves, and the ripe seeds were gathered. These were now found to be made up of one-quarter possessing the recessive character, and three-quarters with the dominant one. All the seeds were sown, and the plants allowed to fertilize themselves. It was then found that the recessives remained purely recessive, that is, the seeds were all green, and this was the case in all subsequent generations; whereas the dominants were found to be unlike among themselves, being made up of two sorts: (*a*) those which, on sowing for further generations, produced, like the recessives, all pure dominants; and (*b*) those which gave rise to mixed offspring, partly dominants, partly recessives, and, in fact, in the

proportion 2 : 1. Thus it is seen that the 75 per cent were not all pure dominants, but were made up of 25 per cent such and 50 per cent cross-breds, the latter exhibiting only the dominant character. The process of breaking up into the parent forms is thus continued in each successive generation, the same numerical law being followed. This is—

25 R : 50 D R : 25 D,

where R and D signify recessive and dominant, and D R progeny which possess both characters, though in the first instance exhibiting only the dominant one (fig. 431).

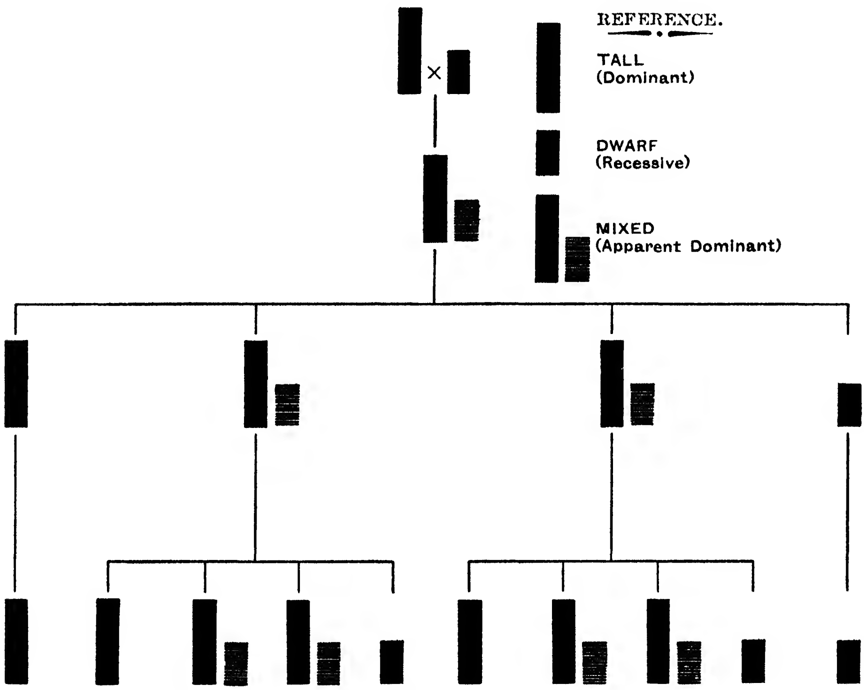

Fig. 431.—Diagram illustrating Mendel's Law

Similar experiments were made between pairs of varieties exhibiting two characters of the seven, and the results, though much more complex, showed the operation of the like law. If the characters were R and *r* and D and *d*, the numerical proportions were—

$$\underset{(1)}{9\,Dd} : \underset{(2)}{3\,Dr} : \underset{(3)}{3\,Rd} : \underset{(4)}{1\,Rr}.$$

On cultivation group 4 was found to give rise to all recessives in both, group 3 were partly recessives and partly mixed cross-breds, and group 1 pure dominants and recessives (as to one of the characters), dominants and recessives (as to the other character), and pure recessives, the ratio approaching 1 : 3 : 3 : 9. For more than two characters the results,

though in conformity, are still more complex. It is quite impossible in the space at disposal to give an account of all the more recent developments of "Mendelism", and the researches are still in progress. "Each new riddle solved propounds new riddles, and strengthens the hope of their solution." Certain general aspects of the Mendelian phenomena, however, require notice. They demonstrate what, for other reasons, is apparent in embryology, that each gamete, egg, or sperm is "pure" or single in respect of the characters it bears. This Mendel recognized and insisted upon. In the egg or the sperm of a plant or animal there is no mixing of characters, such that, for example, a particular sperm might bear or contain the potentialities of both height and dwarfness. Each egg or sperm contains the potentialities of one complete set of characters, and of one only. In fertilization there is a union or joining together of two such complete sets of characters, and of two only. In the germ-cells these two sets are present and united, though in the individual itself containing the germ-cells only one of any two characters is manifest. In the gametes either character may reappear. In the Mendelian cases, which are not universal in biparental (bisexual) reproduction, these characters reappear according to the Law of Probabilities. It is not so much the dominance of certain characters, or the latency of others, which, in respect of the question of variation, requires elucidation. It is the non-elimination and disappearance of characters which call for explanation. The answer was really given by Mendel himself. "No one will seriously maintain that the development of plants in the open country is ruled by other laws than in the garden bed. Here, as there, changes of type must take place if the conditions of life be altered, and the species possess the capacity of adapting itself to its new environment." And again: "Even here (*i.e.* in certain leguminous plants like and including the pea) there have arisen numerous varieties during a cultural period of more than a thousand years; these maintain, however, under unchanging environments, a stability as great as that of species growing wild".

NATURAL AND ARTIFICIAL VARIETIES.—The varieties which, under the action of artificial selection, Man produces, like the various sorts of pigeons, for example, may be termed *artificial varieties*. They stand contrasted with the varieties occurring in nature, or *natural varieties*. Artificial varieties are such as are not, as a rule, adapted to the environment, and when intercrossed they do not breed true, but "revert" to the mean, *i.e.* to the natural variety or varieties from which they sprang. Natural varieties, on the other hand, may be defined as such as are adapted to the environment, and as long as this is constant, on being interbred, they do not "revert", but in subsequent generations the characters of the two parent natural varieties reappear, because each of them is adapted to the environment, and it is a matter of indifference which of them be chosen. In the Mendelian experiments, in the cases where Mendelian results are obtained, natural varieties are dealt with in the first instance. As the environment was constant under the experiments, each of the characters dealt with was equally suitable and adapted to it, and no one could be selected to the exclusion of the other. Therefore they would be equally

favoured, and the results would come about according to the mathematical laws of probability, which has been found to be so.

The reappearance of characters in this way, in man and other living things, will often be brought to pass by the like cause, the absolute equality of the characters of qualities under an environment which has been constant, or which, at all events, has not caused any of them to change. It is this, with dominance or prepotency (a kind of close-linking of characters in the set), which accounts for the phenomena of "atavism", or of "reversion" to, for example, a grandparent. When the reduction is merely the undoing of the previous union, it must be a matter of the mathematical probability which of the two nuclear halves of a germ-cell shall be chosen to form the gamete, for one must be rejected; and thus, on occasion, the sperm or the egg may mimic, even in minute details, the characters or qualities of some near "ancestor", for instance, of a grandparent.

Biometricians refuse to consider such phenomena except by an "appeal to ancestry". The facts of embryology do not support the view that much, or anything, is to be gained by an "appeal to ancestry". In the union of egg and sperm there is the union of but two sets of characters, and not that of "x" sets, derived from as many "ancestors". As in the reproduction of bisexual individuals these unite with the gametes of other individuals, in this union, a priori, there would be for any particular character four possibilities, not more. Take the four grandparents, and consider one character in the gamete of each. Assume, further, that in the two following generations there be no complete elimination of any character, and that this reappear in some of the gametes. The characters may be A, *b*, C, *d*, the first two being conjoined in the germ cells of the father, the second two in those of the mother, and the large letters being dominant or prepotent. In the gametes of the parents the representative of this character may be either the dominant one or the latent one. That is to say, any particular gamete may contain any one of the four characters, A, *b*, C, *d*, and suppose then that *b* and C be conjoined to form the grandchild, and that C be dominant in it, its gametes will contain either character *b* or C. Therefore, if this gamete *b* unite with another, *e*, and if in the development *b* be the dominant one, the result will give the appearance of a "reversion" to the grandparent *b*, after a dormancy through two generations. But there is no room for more "ancestors".

DISCONTINUOUS VARIATION.—To understand the meaning of this, and the significance it has acquired in the light of its latest development, the mutation theory of de Vries, it is necessary to go back a little and to recall that Darwin and Wallace regarded natural selection as acting upon small variations, which then were supposed to be constantly happening. It had not then been recognized that most, if not all, these variations were oscillations to and fro about the mean of the variety, what we now, with de Vries, term fluctuations. Bateson, in 1894, in his voluminous *Materials for the Study of Variation*, demonstrated that instead of variations forming always in this way a continuous series, showing a gradual passage from one structure to another, they were not infrequently discontinuous, the variations from the mean not being connected by inter-

mediate links. The later experiments of de Vries have confirmed this. "In proportion as the transition from term to term is minimal and imperceptible, we may speak of the series as being *continuous*, while in proportion as there appear lacunæ in it, filled by no transitional forms, we may describe it as *discontinuous*."

THE MUTATION THEORY.—The theory of mutations is due to Hugo de Vries, of Amsterdam. By his patient experiments, carried on during many years, new light has been shed on current beliefs, that species and varieties are slowly changed into new types. Under his theory and the results of his researches new varieties would appear to come into being by sudden leaps or mutations (discontinuous variation). As de Vries has demonstrated by his experiments upon the evening primrose, *Œnothera Lamarckiana*, the parent-form may remain unchanged while repeatedly at irregular intervals giving off new forms or varieties, and as a rule these can be fixed and breed true among themselves. The experiments began in 1886, and over 100 species of plants were tried first of all, until a suitable one was found. This form, *Œnothera Lamarckiana*, was met with in a deserted potato field at Hilversum. The earlier European history of the plant is not known, but it probably came from its native home, America. Its chief peculiarity was its variability. In the first year of the observations it had given rise in the open field to seed of two new forms, unlike the parent form in many respects. These de Vries named "elementary species", by which he meant to define a group of individuals agreeing among themselves and differing from other allied forms in certain characters, which bred true. The new forms, on self-fertilization, bred true. They had not been previously recorded, nor were they present in the herbaria of Leyden, Paris, or Kew. Some of the parent forms and the new ones were then taken for further experiment in the Botanic Garden of Amsterdam.

From all these forms, in the course of extensive experiments, and whilst the new forms themselves persisted, still other new "elementary species" suddenly arose in the same manner as the original two. In all, seven constant "elementary species", *Œ. gigas*, *Œ. rubrinervis*, *Œ. oblongata*, *Œ. albida*, *Œ. leptocarpa*, *Œ. lata*, and, lastly, a dwarf form, *Œ. nanella*, as well as some inconstant and some sterile forms. Some of the forms appeared anew again and again, and five of them were afterwards found in the field or sprang up from seed obtained there. According to the author, these new "elementary species" appear suddenly without any transitions, and not as single variations, but as numerous individuals at the same time. The changes in organization in the plant are in many particulars, and do not relate only to some particular structure. When intercrossed, these "elementary species" are found to follow the Mendelian laws, both of the original types appearing in subsequent generations.

As "elementary species" are said to occur numerously when they are found at all, the supposed "swamping effects of intercrossing" are thereby discredited, and if it could be proved that all variations appeared in the like manner, then discontinuous variations, as opposed to slow, fluctuating variation, would appear to be Nature's method. This, of

course, differs entirely from the sort of variation employed by man in artificial selection. The results of the experiments do not appear to be open to doubt, and perhaps their nature may be made clearer by describing the "elementary species" as natural varieties, that is, as varieties occurring in nature, which are adapted to the environment.

EVER-SPORTING VARIETIES.—In contrast to the mutations de Vries places the ever-sporting varieties, such as the striped larkspur, which for hundreds of years has continued to produce striped and unstriped flowers. The change, which is always recurring, is from small stripes to broad stripes, and back to pure colours. "The constancy consists in eternal changes, while the variation is absolutely constant." Another instance is the common snapdragon, of which the striped variety is constantly occurring, but cannot be fixed. According to de Vries, the average variations, which oscillate to and fro about the mean of a variety, lead to nothing new, and may not be regarded as the material used by Nature for producing variation or giving rise to new species. These are the kinds of variations dealt with in biometrical researches, and by him they are termed *fluctuations*. Mutations, on the other hand, are of the nature of single varieties or "sports". Comparatively speaking they are rare and sudden in their appearance. "When a mutation has occurred, a new species (that is to say, natural variety) is already in existence, unless all the progeny of the mutation be destroyed", and this is because such a new natural variety is one adapted to the environment. Again, in contrast to the mutations, de Vries distinguishes *retrograde varieties*, which are forms that have thrown off or lost some particular feature of their ancestry. They appear in the same way as mutations, but are always characterized by apparent loss of something, thus pigment, hairs, or spines, usually one character only. "Natural selection may explain the survival of the fittest, but it cannot explain the arrival of the fittest."

FILIAL REGRESSION.—What is termed "regression" is the continual tendency to restore the specific average. Thus, the children of a specially gifted father are on the average not more likely to inherit his gifts than the children of average parents are to be gifted. Individuals out of the ordinary tend to produce offspring which "revert" to the mean. Fathers of a height of 6 or 7 ft. do not, as Frederick the Great imagined, tend to beget sons of a similar tallness, "but an array of sons of a mean height different from that of the father, and nearer the mean height of sons in general. Under regression there is a striking general resemblance between successive generations of a people." The individuals of any variety, man for example, are not all the same in any given character, and they do not tend to reproduce a given character, such as height, in their offspring, nor do exceptional individuals tend to reproduce offspring exceptional in similar respects. For example, the number of large scales or spines along the middle line of the back of a species of skate may vary from thirteen to eighteen within the species. This does not mean that a given fish with eighteen such scales will tend to have offspring all with the like number of spines, but that the latter will "regress" towards the average mean, and if this be fifteen, then among them there will tend to be more

with this or about this number than with the larger number, eighteen. "Filial regression", it should be noted, is identical with what de Vries terms "fluctating variability".

CHAPTER IV

THEORIES OF HEREDITY

The phenomena of heredity and genetic variation appertain to the germ-cells, that is, they are germinal in nature. All ancestry passes through a continuous line of germ-cells, and never through the cells of the individual (somatic cells) containing the germ-cells. An "inheritance of acquired characters" is impossible, for there is no handing on of anything. The individual is merely a terminal and lateral offshoot. In the higher animals direct development, a building up of the individual, and a somatic origin of germ-cells do not exist. The recapitulation theory is without any basis in the facts of development. The mode of development is not "egg—embryo, egg—embryo", but it is "egg, zygote (fused egg and sperm)—asexual generation—primary germ-cells—secondary germ-cells—oocytes, &c.—gametes (eggs and sperms)", "the embryo" arising by the unfolding of *one* primary germ-cell, the others being so many identical understudies. The formation of an individual is a mere incident in a certain chain of events.

GENETIC VARIATION.—The problem of *genetic variation*, as opposed to *somatic* or *individual variation* is an embryological one. Each egg or sperm must be regarded as containing one complete set of all the potential characters or qualities necessary, as unconscious memories, not material entities like biophores, to form an individual of the species. At fertilization *two* sets of these are somewhat loosely joined together. In the developing embryo only one complete set of characters is unfolded, and while the other corresponding set remain dormant, the set employed may be made up of any characters from either of the two sets, but composed of one set only.

GERMINAL ELECTION AND ELIMINATION.—Turning to the germ-cells, each of these possesses the two sets, and later on, at the "reduction", the twofold set becomes diminished to one set only, by the elimination of a complete set, made up of characters from either set. The true meaning of the "reduction" of germ-cells to the single original condition is the elimination of one set of characters or potentialities, such that the ones more suited to the environment are chosen, the others rejected. The two sets, since cells are living organisms, must be influenced by the environment, nutrition, climate, &c.; some it will favour, and these will increase in import, others will be unfavourably influenced or neglected, and these will diminish. At the reduction there will be a "settling-up". This elimination of characters may on occasion become an elimination of individualities, a

casting out of "ancestors". Under the influences of the environment the process becomes *a self-adjusting mechanism*, the up-and-down oscillations of the characters of the two sets endeavouring to follow and compensate the changes in the environment, and with alterations in the latter the result must be genetic variation.

Even if Nature selected individuals, and rejected or eliminated unsuitable ones, the results would be as nothing compared with germinal election of fit and elimination of unfit potential characters. Nature notoriously cares nothing about individual life, she can exert her choice, and she does it among the germ-cells, among their characters. With a constant environment, or with what is assumed to be such, man first rejects (individuals of) certain varieties, and in this way favours (individuals of) other varieties. He then intercrosses the latter. This is not Nature's way. When she causes variation, she initiates it by altering the environment. Adaptation to the new environment then becomes necessary; some varieties may attain to this, others fail. The latter will then be eliminated, either as individuals or by germinal elimination. New varieties then arise in adaptation to the new environment, for everything in living organisms depends upon adaptation to the environment.

Germinal election and elimination offer adequate and simple explanations of all the phenomena. They throw light upon the Mendelian cases, which are by no means universal in biparental reproduction, on mimicry, as adaptation to environment, on slum life and its features as the like thing, on protective coloration, bud-variation, and the loss of organs such as the hind limb of the Greenland whale, to explain which latter Weismann found it necessary to evoke a new principle, the cessation of natural selection, or *panmixia*. They explain why, for example, the giraffe has a long neck. This is not because, as the Lamarckians assert, it was in the habit of stretching its neck, the effects of this being handed on by an inheritance of acquired characters; and, again, not because, as the Darwinians maintain, by natural selection Nature picked out those individuals whose necks tended to be long, and destroyed those with shorter necks, but simply because Nature eliminated in the germ-cells those potentialities which tended to the production of a short neck, while she fostered those other characters of the other parental line, which tended to the formation of a longer neck, and she increased the value of these from generation to generation. The principle resulting in the self-regulating mechanism offers a simple construction of all the phenomena of variation, and a far more natural one than "Natural Selection" or the "Germinal Selection" of Weismann. Under it there is no necessity to evoke these.

HERING'S THEORY OF UNCONSCIOUS MEMORY, THE "MNEME", AS THE BASIS OF HEREDITY.—Owing to the facts of animal development being what they are, viz. that "the embryo" or individual is a mere incident in a certain chain of phenomena, that at the epoch prior to the unfolding of this embryo it and its germ-cells are identical in all potential characters, so much so that, were all the germ-cells to develop and form embryos, these and "the embryo" would all be identical in all potentialities and characters, certain conclusions as to the true nature of what we term

heredity may be drawn. Identical twins, of which as a united pair, abnormal in this respect, the Siamese twins furnish a well-known example, are among the greatest wonders in animate nature. Some of the problems of identical twins were considered by Francis Galton in 1875. He traced the after-life of about eighty of them as far as he could, and he noted, what has often been observed by the writer in recent years, the frequency with which both suffered from some serious ailment at the like period of their lives. This, as the writer has found, is particularly the case with cancer. In some cases he found evidences of a remarkable association of ideas, and Wilder has commented on the fact that such twins tend to regard themselves as one individual, and to speak of themselves as "we". But until this was determined theoretically, and established in fact by the writer, it had not been recognized, that *two* sorts of identical twins occur. In the ones, AB and AB, we deal with individuals, as it were, moulded in the same mould, while in the very much rarer second kind, AB and BA, it is found that the one twin is in all respects the looking-glass image of the other, and that this image-reversal extends even to the internal organs, for one of the two, BA, has reversed viscera. These do not end the possibilities, for there is an armadillo, *Praopus hybridus*, where regularly and normally from seven to twelve identical embryos or individuals, all of the same sex, arise from a single egg, as ordinary identical twins are known to do. Such facts as these are as a rule not taken account of in any theory of heredity, except in that based in an actual continuity, not of a hypothetical germ-plasm, but of germ-cells. Only under such a conception are these phenomena to be accounted for and explained. In the like fashion only under this view can due weight be given to Professor Ewald Hering's theory of (unconscious) memory as a general feature, an attribute, of organized matter. When Weismann imagined a hypothetical germ-plasm, when Darwin thought of "pangenes", when, in fact, a whole host of attempts were made to solve the problems of heredity and variation apart from embryology, and without regard to such general principles as the foregoing, these endeavours were doomed to disaster, because built on sand, or—in the air!

If we recognize with Hering, and this has now been done by the writer, by Richard Semon, and by Francis Darwin, that unconscious memory in Hering's sense is sufficient to account for heredity as exhibited by living things, much that has been imagined becomes not merely futile, but an unnecessary multiplication of causes.

Hering points out that the forms of curves and surfaces, which the mathematician conceives or finds conceivable, are much more numerous and manifold than all the forms of organic nature. Break such a curve into almost an infinite number of pieces, then all the fragments will appear much more similar to one another than one germ to another. When the mathematician allows such a fragment of a curve to grow, it does this only within the limits of shape and form which condition the original.

Analogy is dangerous, especially in science. By cell-division of the forerunners of germ-cells, of the primitive germ-cell, of every development, Nature has a perfect means of "breaking up" the original "curve" of that

germ-cell into numbers of others, all with the like potentialities of growth, characters, &c. These products by cell-division are right-handed and left-handed. If two right-hand products grow and develop, they result in identical twins "out of the same mould"; if a right and a left-hand product, then in "looking-glass image" twins.

Everything in animal and vegetable life, in our own lives, depends upon memory. We link together yesterday and to-day, our childhood and old age, by memory, and but for it there would be no continuity. Memory is a property of living matter. "The whole individual development of a higher animal forms from this point of view a continuous chain of recollections or memories of the history of development of that great series of beings whose last link this animal is" (Ewald Hering).

Of two primary germ-cells of any animal development one becomes the individual, the other continues the cycle of the germ-cells. So alike, so identical, are these at the start that, had both developed, they would have been identical twins. Neither of them in the ancestry had ever been an individual higher animal, neither they nor their unicellular ancestors, other germ-cells, had ever formed part of such. But this "ancestry" is continuous with a long line of germ-cells, and at regular intervals of time these were like certain sister-cells, which did develop and form embryos.

In the drama of heredity there are always under-studies, which for a certain essential period are endowed with all the properties of that germ-cell from which the player arises. Rarely (identical twins, &c.) are any of these "under-studies" employed on the stage, but some of them in new guises are the immediate "ancestors" of those which become the acting characters in new scenes in the cyclical drama of life. What interpretation shall be put on all this? The characters of germ-cells are not actual entities, but potentialities, possibilities of doing certain things, of bringing about certain results. If, as Ewald Hering and others since him have maintained, memory be an attribute of living matter, whatever "living matter" itself be, then all the wonderful and infinite variety of animate nature has its fount in the unconscious memories of germ-cells.

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PHYSIOLOGY AND MEDICINE

BY

BENJAMIN MOORE, M.A., D.Sc.
Professor of Bio-Chemistry in the University of Liverpool

PHYSIOLOGY AND MEDICINE

CHAPTER I

INTRODUCTORY

MEDICINE AND MEDICAL SCIENCES.—Medicine and surgery, as well as the cognate group of subjects known as the medical sciences, such as anatomy, physiology, pathology, and therapeutics, are all closely related to the mother science of biology, and in the main consist of applications of general biological principles to the prevention of disease or to combating disease after it has invaded the body. The ultimate goal of all this great group of studies, in addition to their own intrinsic interest, is thus the preservation of good health, or a normal functional state of the body, in man and in the animals of economic importance, which are practically essential to human existence.

APPLICATION OF RESULTS.—There are two chief ways in which the results obtained in such studies can be applied to the problem of health preservation. The most fundamental and rational of these methods is the prevention of disease by the application of general biological or physiological knowledge, so as to secure better sanitary conditions of life and the destruction of those lower organisms which carry disease to man and the higher mammals. This application of biology is known as HYGIENE in the case of the individual, and as PUBLIC HEALTH in the case of the body corporate. It forms alone a very large branch of applied biology, which fortunately grows ever stronger in popular favour, and in time is destined to represent the most important service that the medical profession can render to humanity.

The second method consists in the treatment of disease after it has invaded the body, so as to mitigate its effects, or, where possible, eradicate it.

On account of the defects at present existing in our knowledge, and the incompleteness of application of the public health system, aided by the deplorable ignorance of the general laws of hygiene in such large masses of humanity, this second method of treating disease at present occupies the attention of the vast majority of members of the medical profession; and since the innocent too often suffer with the guilty, the practice of this important side of medical science must continue to consume a large

share of attention and labour which could otherwise be devoted to general hygienic measures and systematic control of the sources of disease.

NATURE AND DISEASE.—We shall see later that Nature herself points out the necessity for applying these two fundamental methods, and that the body possesses in its normal organization, in the first place, means for resisting the entrance of disease, and secondly, when these forces have been overcome or weakened, has also the power of continuing the battle in the system, killing and destroying the infecting organisms, producing antidotes to protect the tissues from injury by their poisons, or *toxins* as they are called, throwing out chemical products to aid in recuperation, and forming fresh living units or *cells*, either to take the place of those destroyed by injury or disease, or to fashion a boundary wall for imprisoning and separating off noxious intruders. Without this important provision of nature the treatment of disease would become almost impossible, and in many cases the physician's or surgeon's services consist mainly in arranging the best possible conditions for the natural contest between the organism and its invaders.

NATURE OF DISEASE.—It is well to realize at the outset that disease is in nearly all cases a combat between different forms of living structures —a struggle between different organisms opposed to each other—and that these opposing organisms live or die under much the same conditions of environment. Almost the same types of nutriment feed one as the other, and the same general poisons kill both organisms—that is to say, are equally disastrous to host and parasite.

DIFFICULTY OF DEALING WITH DISEASE.—It is exactly this condition which makes the problem of eradicating disease, when once it has entered the body, such an exceedingly difficult and intricate one; for unless indeed the disease or abnormality is so locally situated that the surgeon can remove it or restore normal arrangements, it becomes necessary to seek out some substance which is deleterious to the invading organism, but innocuous to the living cells of the host, or at least some substance which is more powerfully adverse to the parasite, so that a discriminating dose can be employed by which the parasite is killed without permanent injury to the host. This process is like that of constructing a key to one of two most intricate locks which closely resemble each other, so that the key may actuate one lock and not the other. In certain cases modern medicine has provided such keys, or *specifics* as they are termed; but in the majority of cases they are still to be discovered, and here lies the great work of modern experimental therapeutics which is now being keenly investigated in many quarters.

GERMICIDES.—A general drug or germicide which could chemically anchor on to the living matter of parasites (or even a class of parasitic organisms), and so destroy their activity, but would be inert upon the living matter of the cells of the higher mammal, would be a much more valuable possession than the philosopher's stone of the ancient alchemists, and a modern rival of their vainly sought *elixir vitæ*. Fortunately there do exist minute differences in the chemical conformation of the molecules forming living matter in the cell bodies of parasitic organisms and host

cells respectively, which allow the possibility of treatment in many cases, and patient research is gradually increasing the number of such cases and giving hope to the increasing band of medical researchers of final conquest in all.

NATURAL PROTECTIVE SUBSTANCES.—Recent work has, moreover, shown that in a great many cases the animal body is the best laboratory for the making of such protective substances, and the use of lower animals of species which are more or less immune to certain diseases, for the manufacture of such specifics, which can afterwards be used for the treatment of less immune animals and of man, forms one of the greatest achievements of modern medical science, full of bright hope for the future, and every day becoming more and more largely applied.

STUDY OF THE BODY IN HEALTH.—Since the aim of all medical science is to protect, regulate, and keep in normal condition the living tissues of the body, and since, as we have seen, the enemies to the healthy normal condition are themselves living organisms, it becomes obvious that in order to build up a rational system of medicine it is necessary to study and understand the normal working of the body and the various uses of the different organs in the economy of the body; for unless the healthy action of the different parts be understood it will be impossible to understand the derangements which occur in disease. Just as a mechanician cannot understand and put in order a piece of defective mechanism, such as a watch, for example, unless he knows the normal working of each part, so in the complicated mechanism of the body the physician cannot attempt to restore normal working order in disease unless he possesses some acquaintance with the normal operation of the different organs in the healthy body.

PHYSIOLOGY.—That department of Biology which deals with the normal offices or work of the different parts of the healthy body is known as Physiology, and forms in itself a vast science which has grown enormously in the past fifty years, and has for purposes of study been divided into several branches, each possessing its own special literature and special band of workers. Thus the portion of the subject which deals with the minute structure of the parts is termed Histology, and that part of histology which more especially deals with the growth and division in reproduction of the minute parts of the tissues, which are called cells, is termed Cytology. The chemical character of the body and its minute units or cells, the products formed by the activity of the cells, as well as the character of the food and its changes, and the nature of the waste products formed in the body, are dealt with by the science of Biochemistry; while the reactions of the tissues to physical stimuli, and especially those of the muscles and nerves and of the nervous system, form the division of the subject known as Bio-physics.

PATHOLOGY.—The science of pathology deals with the morbid changes occurring in disease, and the effects of infecting organisms on the tissues; it has similar divisions to physiology, and in addition divisions belonging to the classes of infecting organisms. Thus Bacteriology is in reality a branch of botany which has been largely annexed by pathology, for the

bacteria of disease are minute plant structures consisting of a single cell which are visible only by means of the higher powers of the microscope. Another division of pathology which is rapidly assuming large dimensions and, like bacteriology, becoming firmly attached to medicine, is that known as Proto-zoology. This now forms a large portion of the subject of tropical medicine, and deals with minute microscopic unicellular organisms belonging to the animal kingdom and termed Protozoa. Many diseases, especially those of tropical climates, are caused by the invasion of the blood and tissues by these protozoa (see p. 143). In addition to the parasitic protozoa there exist countless forms which live independently, and are not related to disease; these still remain more peculiarly in the domain of the biologist, and form the most numerous group of living creatures studied by that science.

Thus there are many divisions of the study of living organisms, rendered necessary by the vastness of the subject and by the corresponding necessity for special study and research in order that new advance and discovery may be made. But it cannot be too strongly urged that the object of study is the same in all, namely living matter and living creatures in their different and countless varieties, forms, and phases of activity. There are the same fundamental general laws governing all, and these form the basis of all biological study, although methods may vary and specialization be essential.

NO SHARP BOUNDARY LINES.—It will have been gathered from the preceding statements that there are two main divisions of study, the normal and abnormal, or the physiological and the pathological; but it must here again be borne in mind that what is pathological for the host is physiological for the parasite, so that once more we see that there is a kind of unity of all biological and of all medical study, and that the various divisions exist for purposes of convenience and description and not on account of any real intrinsic differences of a broad character in the material studied, or in the character of its life and the manifestations accompanying its activities.

STUDY OF PROTOPLASM.—It is therefore essential to a rational knowledge of the subject that we should consider at the outset the ultimate nature, so far as we can analyse it and understand it, of the similar material (protoplasm) which forms both the minute living parts or cells of our own bodies and those of the higher animals, as well as the minute bodies of those parasites which, as minute bacteria of vegetable origin or minute protozoa of animal origin, infect the body and give rise to most diseases. We shall also have to consider that service which in the complicated bodies of higher animals is rendered by one class of minute units or cells to the other classes of cells composing the body. When this service, without which life in the higher animal would be entirely impossible, becomes perverted, diseases due to abnormality of function arise apart from the presence of parasites. These diseases form a most important and interesting class, in the knowledge of which immense progress has been made in recent years although much still remains to be done.

Importance of Biology and Physiology.—It is sometimes urged that too much time and labour are spent upon biology and physiology, to the disadvantage of the practical and clinical study of disease; but there could be no greater mistake made than this view, which rests upon an entire misconception of the situation. The whole fabric of medicine is based upon our knowledge of the physiology, using that word in its broadest sense, of man and of the parasitic micro-organisms, for disease changes are the physiological reply to altered conditions of stimulation in various ways of the living cells. Without progress in such knowledge medicine cannot advance, and the great onward movements in recent years in the treatment of disease have been heralded and ushered in by great fundamental discoveries in physiology and those allied sciences which have arisen as branches from it. It is true that there are many methods of approach to the study of the living cell, its normal functions and their perversion in disease, and clinical observation at the bedside is perhaps the most important of all these methods; but it is incomplete and imperfect in itself, and the observer is defectively equipped if he be not a trained student of biology and physiology who recognizes that he is continuing, at the bedside and in his treatment, a branch of biological research and application.

General Principles.—Until the general principles have been discovered by the research of the medical sciences there can be no application of them at the bedside, and the discoveries must be made by experimentation either in man or in animals. This does not exclude the fact that most important discoveries have been made by direct clinical observation, for here the methods of scientific enquiry have been used. The physician or surgeon has closely watched the experiments which disease of natural incidence has produced for him in the patient, on the same principles as the physiologist or pathologist conducts similar observations upon artificially produced conditions, where the problem can be more isolated and the producing cause is more clearly understood. Further, in the clinical treatment, when new ground is broken or new advance or discovery made, it must inevitably be done by experimentation on the lines suggested by the observations, or by empirical testing within safe limits, and here again the experimental methods of the laboratory are closely followed.

Research.—If the plea for the systematic study of pure natural science requires further strengthening in the eyes of the so-called "practical man", it may be urged that the most glorious and far-reaching applications of both practical medicine and practical surgery which adorn those sciences in the present day, and place their present position in such bright contrast to that which they held little more than a generation ago, have arisen from the patient work of quiet observers, who, dreaming not of applications, laboured to discover Nature's secrets for the pure love of study and the conquest of unknown and unexplored territory of natural science.

Spontaneous Generation.—To take but one example of this: there raged, about forty years ago, a long and, it must be admitted, somewhat

acrimonious dispute between biologists as to whether micro-organisms were or were not capable of spontaneous generation in certain nutrient media in which they were found to flourish. One set of disputants stoutly argued that such a mode of production was not only possible but continually occurred, and they produced experiments in support of their contentions. They showed that, after all life had been destroyed by raising the temperature of the culture medium to the boiling-point and then carefully, as they supposed, preserving it from contamination from the air or other sources, in a few days the medium was swarming with micro-organisms, which they argued could only have been spontaneously generated and did not arise from parent organisms. The other set of disputants argued that the well-observed facts of histology were all against such spontaneous generation, and that the means for preventing re-contamination, perfect as they appeared to be, must have been faulty, and allowed of the admission of germs. The subject was finally set at rest by the crucial experiments of Louis Pasteur, who showed that traces of moisture in the cotton-wool plugs used for filtering off the germs floating in the air served the purpose of allowing the contaminating germs to reach the culture medium within, and that if *dry* cotton wool were used, after sterilizing, as it is now called, by heat, or, still better, if the culture medium, after sterilizing, were hermetically sealed off in a glass vessel, then no micro-organisms arose within, no matter how long an interval of time elapsed, and the medium remained sweet and pure.

APPLICATIONS OF PURE RESEARCH.—The discussion of spontaneous generation might seem to be purely theoretical, of great scientific interest perhaps to workers in biology, but of no practical import to the great world beyond, and indicating no great practical applications, either in medicine or surgery. But that one discovery in pure unapplied science, that one fast-proven fact in biology resulting from it, proved to be the parent germ from which have developed all the modern advancements of our generation in medicine and surgery. It has saved countless lives of men and animals, and will continue to do so through the coming ages, by rendering possible surgical operations which before were utterly impossible; it has rendered the study of disease germs possible to the physician and bacteriologist by giving him the means of cultivating them and isolating them one from another, so as to obtain what are termed *pure cultures*, containing only one species of organism, which can then be studied in this state of isolation, and its causal relation to a given disease made manifest. All this arose from an apparently purely theoretical discussion on spontaneous generation, and such examples of practical applications arising from pure philosophical study of nature could be multiplied by the score.

CHAPTER II

THE CELL: GENERAL CONSIDERATIONS—AMŒBOID CELLS—FIXED CELLS—THE NUCLEUS

GENERAL CONSIDERATIONS

THE CELL.—The example given in the last chapter is not a digression from our main subject, but rather forms a fitting introduction to our consideration of the normal life of the physiological unit, namely *the cell*, its structure, its life-history, its chemical composition and affinities for the substances which nourish it and how it attaches itself to these nutrient bodies, its relationship in the higher animal to cells of other types co-existing in the same body with it, and its reactions to the stimuli of disease—that is to say, to abnormal conditions of life.

LIFE FROM LIFE.—The natural law that living matter can only arise by the operation of pre-existing living matter is hence as fundamental a conception in biological science as is the law of gravitation in physical, or that of definite combining weights in chemical science. It is true that at present we can probe no deeper into what this condition of matter which we designate as "living", and which expresses itself by certain energy phenomena evident to the senses and met nowhere in nature except in living structures, has for its ultimate basis and cause, than the astronomer or physicist can pierce into the cause of the attraction of masses for one another, or how the poised equilibrium of the universe came into existence; or than the chemist can explain the cause of that peculiar attraction of dissimilar forms of matter which he disguises under the name of "chemical affinity", of *why*, for example, the simple combination of hydrogen and oxygen to form water takes place inevitably under given conditions. The ultimate *why* is hidden from us in all branches of natural science, and the biologist is no worse off in this respect than other natural philosophers. He has, like them, having accepted this fundamental fact, to deal with an intrinsic set of energy phenomena belonging to matter in a given condition, with energy phenomena which do not exhibit themselves in matter not in the given condition of life, and which can only be impressed upon matter by the influence of other living matter.

ENERGY PHENOMENA.—It must be realized that in biology, as in every division of science, the observer has to do with a set of "energy phenomena", and that energy changes, with the accompanying changes in the matter involved, are the essential things concerned in every experiment and every natural act.

MORPHOLOGY.—It is well to keep this fact strongly in mind, because the issue is likely to become obscured by the purely outward and visible signs of change in the material, giving rise to the multitude of forms and structures in cells and organisms, which form that branch of biology known as *morphology*, or the study of form and the relationships of various forms to one another (Gr. *morphē*, shape; *logos*, discourse). This

interesting study has given rise to that vast classification of existing types of living organisms which is indeed essential to progress and constitutes at the present time the vast bulk of biology. None the less the root cause of all this varied morphology must not be forgotten or pushed into the background, since this is the real connecting link in the whole system. All the multitudinous forms of living beings have this in common, which distinguishes them from the objects of the inorganic world, that they are *alive*, and hence are capable of manifesting, in varying quantitative degree but in the same qualitative sense, distinct energy phenomena, the nature of which in a typical case we shall presently consider. It is indeed purely these energy transformations in living matter, and the power they furnish for initiating certain changes, that give the only reliable criterion of life in any structure. The form, composition, and structure of living cells vary enormously, so that there is nothing which can be taken as a type of all forms in respect to these material properties, unless the means by which the variations are brought about are considered and taken into account. Then correlation soon appears, and it is seen that the variations arise from the functional character of the cell and the work which it has to undertake. In other words, the energy processes come to bear, aided by variations brought about by what has been termed "environment", that is, the play of outside forms of energy upon the cell. The result is that the living cell, which in its young or embryonic form has a typical structure varying but little from one organism to another, becomes by the action of these two factors a quite different structure in outward form and in the character of its work, serving some one particular purpose in the organism or community of cells of which it is a member.

PROPAGATION OF CELLS.—Not only does all living matter arise from pre-existing living matter, it is a necessary process in the growth of all living organisms that they should develop, by the operation of the energy factors above considered, from the simple type of a single living cell (see fig. 2 on Plate, FORMS OF ANIMAL CELLS). Thus every organism, from the one-celled bacterium or protozoan up to man, arises in the beginning of its life-history from a single cell. This cell, in the case of one-celled organisms, remains throughout its life an independent unit, and the end of its existence as an individual (unless it perish directly through some change in its environment giving rise to some deleterious influence which terminates its existence) is marked by its division into two or more units like itself, which separate, grow in size, and pass their existence also as one-celled organisms. This process goes on through many generations, but in a great many one-celled organisms is interrupted after the passage of a certain number of generations by a different type of reproduction which corresponds more to the process by which the life-history of more highly organized beings commences, and is supposed to constitute a type of *rejuvenescence* (*i.e.* renewal of youth) of the cell material and energy, and to tend to the preservation of the peculiar characters of the particular species. Without this process it is believed that the strength of the strain decreases and the reproductive power tends

to be lost, so that this process is essential for the continued existence of the species, and must be reverted to after a certain number of ordinary generations.

UNION OF CELLS.—In this process what is termed *conjugation* occurs between two of the one-celled individuals, so that eventually one cell is formed, which then, after a short period of existence, takes up with renewed vigour the process of simple division, or *fission* as it is termed, above mentioned. This mode of commencing the life-history of an individual by the union of two one-celled structures is the only one which occurs in the case of the many-celled organisms, such as man and all animals higher than the protozoa. These more highly organized animals are collectively termed the *metazoa*, in contradistinction to the one-celled organisms called the *protozoa*.

SEXUAL REPRODUCTION.—One of the two primordial cells must be derived from the body of a female parent, and is called the *ovum* (see fig. 2 of Plate, FORMS OF ANIMAL CELLS); the other cell is derived from the body of a male parent, and is called a *spermatozoon* or sperm cell. These two minute organisms, visible only under the microscope, carry each a number of characters in some wonderful way from their respective parents, and in subsequent development, under the influence of nutrition taken in from without, give rise to all the cells and cell products forming the body of the complicated animal, with all its elaborate mechanism. There exists no phenomenon in all nature more wonderful than this, that two microscopic structures should possess the inherent property of developing into a human being, with all those remarkable powers culminating in thought, understanding, and judgment. Nothing that the highest powers of the microscope can reveal is capable of shedding light upon the riddle, and it appears as if structure alone fails to explain the phenomenon, and must be supplemented by the presence of some peculiar type of energy, varying in different species, that initiates and presides over the complicated series of changes by which the fertilized ovum formed by the union of the two cells is converted into the complicated animal.

MECHANICAL DIVISION OF EMBRYOS.—An important argument against the whole plan of the future animal being laid down, so to speak, in the microscopic structure of the fertilized ovum, is the observed fact that if at a certain stage in the development of certain many-celled organisms, such, for example, as the sea-urchin, when a very considerable number of cells have already been formed, the growing organism be mechanically divided into two portions, each portion goes on living and growing, and ultimately develops a considerable way, not towards the formation of a partial individual, but of a complete and anatomically perfect *dwarf* individual. This would appear to demonstrate that the energy factor is capable of initiating structural changes and re-arrangements of the developing organism so as to reproduce from a portion only of the cells a complete individual. Also, there are no very distinctive differences in microscopic structure in different ova; for example, the ova of different species of mammalia are scarcely distinguishable from one another, yet not only from such closely alike ova do we get such very distinct types

of animals, so unlike in appearance, but there are all the differences in finer detail, such as the family resemblances to parents, often transmitted from generation to generation, and in some cases recurring again after having skipped a generation.

FACTORS OF HEREDITY—There are but two fundamental factors which can underlie all this faithful reproduction and breeding true not merely to species but to the individual parents from the single fertilized cell up to an organism like a human being. One of these is structure and almost molecular arrangement passing far beyond our present ken and beyond anything the microscope can show us, and the other factor, no less important though but little thought of or appreciated at present, is the variation in energy forms accompanying such ultra-microscopic variety in structure, and initiating transformations in energy and corresponding transformations in structure and form of the growing organism. So that, given a fundamental original structure in the ovum, inhabited by energy in a corresponding form, the series of developmental changes must take place one after another, each phase giving place by necessity to its successor.

The details in cell division and multiplication, as far as they have been followed by the microscope in ordinary cell division in processes of growth or repair, as also the interesting types, differing from these, in the first preparation of the ovum for fertilization, and the process of fertilization and the curious resemblance between these latter divisions and certain pathological modes of cell division observed in the unbridled and unco-ordinated growths of malignant tumours or cancers, will be reviewed later, after we have considered the physiological life of the normal type of cell and the physiological relationships of different species of cells to one another, and the mutual service they render to one another in that community or commonwealth of cells which constitutes the body of the higher animal.

AMŒBOID CELLS

There exists, widely distributed in nature, one form of cell which on account of its independent existence from other cells, except in so far as its environment is concerned, and owing to the typical manner in which it illustrates the properties of all living matter, is by common consent taken as the prototype for illustrating cell activity. This form of cell, on account of the character of the movements by which it changes its position in the fluids in which it exists, takes in its food, and rejects its undigested or unsuitable solid residues or excreta, is termed the *amœboid* cell (Gr. *ameibō*, I change). (See fig. 1 of Plate, FORMS OF ANIMAL CELLS.)

There are many species of cell which exhibit this amœboid property; some are entirely independent protozoa, living in pond or sea water, another species inhabits the large intestine of man in tropical dysentery and is believed to be the causative agent in that disease, but the most interesting situation of their occurrence is in the blood, body fluids, and tissue juices of the higher animals.

The last-mentioned class of amœboid cells are amongst the most

important of the cells of the body of the higher animal, and form, as we shall see later, one of its chief protections against disease, by taking up, digesting, and rendering harmless invading parasites of many types. (See figs. 1 and 2 on Plate, DESTRUCTION OF MICRO-ORGANISMS.)

LEUCOCYTES.—In the case of animals with a blood supply they are termed *leucocytes*, or white blood corpuscles, but they are by no means confined to the blood in their distribution, since they possess the power of moving freely about in the body by means of the amœboid movement which we are about to describe, and can pass out through the thin walls of the capillary blood-vessels, between the living cells of the wall, by a process of extrusion known as "wandering out" (*diapedesis*). Nor do they arise specially in the blood or tend to accumulate there; they were first studied in the blood, and that fluid forms a convenient source for obtaining them, but they are found in abundance in any tissue and in most of the body fluids, especially where very active work is going on, such as the intestinal wall during digestion, or in the neighbourhood of any inflamed or injured area, or one affected by disease. Such a special accumulation of leucocytes at any area is spoken of as LEUCOCYTOSIS.

The amœboid cells or leucocytes are not then to be regarded especially as an intrinsic element of the blood, but rather as a kind of associated (symbiotic) cell, common to all parts of the body, a sort of normal friendly parasite, originating in the body itself, and possessing most important properties both in health and in disease. Their existence is dependent upon the chemical properties as a nutrient medium of the fluids (called PLASMA or LYMPH) in which they are suspended in the body, but apart from this they are independent in the body and have a separate existence. They live for some time after the blood is shed, and by suitable methods of examination can then be demonstrated under the microscope carrying on their work, and can be made to take up micro-organisms and other nutrient bodies. Also, they can be made on injection to continue to live in another animal of the same species as that from which they have been taken.

The importance of the leucocyte in the economy of all the metazoa is shown by the universality of their occurrence in all animals much higher than the protozoa. Not only are they found in all vertebrate animals, from fishes to mammals, but they are also found in invertebrates. It is hence important to note that they arise in the evolution of the higher animals far antecedent to the red blood corpuscles which are present along with them in the vertebrate blood, and which are only connected with respiration and oxygen exchange and do not possess the multifarious and more fundamental duties of the leucocytes.

USES OF LEUCOCYTES.—Not only do the leucocytes act as a territorial army for protection against disease, but their normal functions in the healthy body are absolutely indispensable; thus, they add many important chemical constituents to the plasma and lymph which are necessary to constitute a perfect nutritive food for the tissue cells, and one valuable property which may be mentioned is that of shedding a ferment when a blood-vessel is injured, which causes the blood to clot and set solid and

so puts an end to bleeding. Were it not for this service of the leucocyte we should bleed to death from even a small wound, and any reparative process or union of tissues after a surgical operation would become impossible. In mammalia the clotting substance is always present in the blood, but remains fluid in the intact vessels until there is a rapid disintegration of leucocytes and accompanying setting free of ferment from their bodies when the vessel is wounded and the blood escapes. Then the substance in the blood which is capable of clotting is acted upon as rennet acts upon milk by the ferment produced, setting into a solid jelly, which plugs the vessels and stops bleeding.

It is interesting that in many invertebrates the blood does not clot as in mammalia, but, when a wound is made, the leucocytes themselves run together and constitute a firm, tough mass, which can scarcely be teased apart with needles; this collects on the jagged edges of the wound, and soon forms an effective plug which stops the bleeding quite as effectively as the differently formed blood-clot of the mammalia.

We have indicated at some length a few of the chief properties of these amœboid cells of the body, because they belong to the most important functions in the economy of the body, and also because much of the recent advance in physiology and medicine has been made by the study of the leucocytes and their work. Nor can our knowledge, much as it has advanced in recent years, be yet said to be more than fragmentary in this important aspect, the study of which is destined to teach us much more in the immediate future in medical science.

The following description of the amœboid cell and the elementary aspects of its life-history should therefore be read not only as indicating the typical work of a cell, but also from the practical point of view as an introduction to what follows later on the work of the leucocyte in resisting invasion by disease.

STUDY OF THE AMŒBOID CELL.—The activity of the amœboid cell can be studied either by using as a type the amœba of fresh water or the leucocytes of human blood (see figs. 1 and 2 on Plate, DESTRUCTION OF MICRO-ORGANISMS), obtained by pricking the finger and mixing the drop of blood on a microscope slide with a fluid known as "normal saline", that is water containing about 0.8 to 0.9 per cent of common salt. A little of some organism such as yeast, or any other minute form, such as any of the disease-producing bacteria, can be added to the saline with which the blood is mixed, so as to demonstrate the taking up or ingestion of the organisms by the leucocyte. If blood be taken it must be kept warmed to about the temperature of the body (about 39° C.) so as to keep the leucocytes alive and active for a longer period.

If the preparation be covered with a coverslip and examined with the ordinary high power (objective) of the microscope ($\frac{1}{6}$ to $\frac{1}{8}$ in.) the first objects seen in abundance are the red blood corpuscles and the added organisms; but in much smaller numbers, probably five or six in each field of the microscope, there will be found a number of less regularly shaped corpuscles, which have not the pale-yellow colour of the red blood

corpuscles or discs, and are somewhat larger in size, as a rule, but vary in size amongst themselves.

These are the amœboid cells, white blood corpuscles, or leucocytes, and at first sight they appear to be motionless like the other cells, for the amœboid movements are not sudden, but are rather slow-flowing movements which are not visible in actual progress to the unpractised eye. If, however, a white corpuscle be selected which is not quite rounded in form, but has one or more protrusions on it, showing that it is not in a resting condition, and if this be watched closely, or, better still, if its outline be roughly sketched on paper at intervals of about a minute (as in fig. 1 on Plate, FORMS OF ANIMAL CELLS) it will be found that its shape is altering slowly all the time by protrusions being thrown out or drawn in, and sometimes it changes its place by flowing bodily into such protrusions. Also, if there are any of the added organisms in its neighbourhood, more prolonged study will show that its movements are related to the situation of these, that protrusions (or PSEUDOPODIA as they are called) are thrown out towards them, and that the organisms end by being engulfed in the body of the leucocyte, where they are digested to serve its nutrition. At a later stage the debris is rejected from the mass of the leucocyte by a simple process of amœboid flowing away of the jellylike protoplasm or substance of the leucocyte.

It is obvious that if this process took place in the body of a higher animal it would rid the animal's blood of the deleterious micro-organism. Thus what is poison to the other cells of the body forms suitable nutriment for the leucocyte. It will be noted that there are no fixed apertures in the leucocyte for taking in food or ejecting debris, but that the soft semi-fluid mass moves by the flowing of the pseudopodia or protrusions, and surrounds food particles, and a similar flowing movement carries the minute organism away from what it is unable to utilize.

It must not be supposed that this feeding, digestion, and ejection of visible particles or organisms which can be watched under the microscope forms the whole of the life and chemical nutrition of the leucocyte. The very movements of the pseudopodial processes appear in many cases to be determined by chemical products emanating from the organisms or particles and dissolving in the fluid. These soluble products stimulate the leucocyte and cause it to send out its protrusions in the direction in which such dissolved chemical products or emanations increase in strength. This process is known as CHEMIOTAXIS and exists not only in the leucocytes but in many organisms, including those of disease, and particularly in those minute disease organisms which move about by means of whip-like processes called CILIA, or FLAGELLA (see fig. 432), and by the oscillations of which they can propel themselves rapidly through the fluids they inhabit. As a result of such movements motile bacteria can propel themselves to situations in the body where the chemical conditions are most congenial to their existence, and thus it comes about that there is often a localization in the body of particular disease-producing organisms to particular regions or particular types of tissues where the chemical conditions are more favourable to them. This at once supplies a simple

explanation of the specific localization of certain infectious diseases to definite regions. For example, the special habitat of the *Bacillus typhosus* of typhoid or enteric fever is the intestinal tract, and here more especially certain patches of tissue called lymphoid tissue, which are separated off and are known as PEYER'S PATCHES.

Even in the case of pathogenic, or disease-producing organisms, which, as far as the microscope can demonstrate to us, possess no special motile apparatus, there is some mysterious type of movement by which they can change their situation according to variations in the chemical composition of the fluid, so that they can accumulate at certain situations, or, if the conditions are unfavourable, can gather themselves together into clumps of individuals, or *agglutinate* as it is termed. This agglutination is seen in both motile and non-motile organisms, and is induced by special dissolved substances in the environing fluid, which are collectively termed AGGLUTININS.

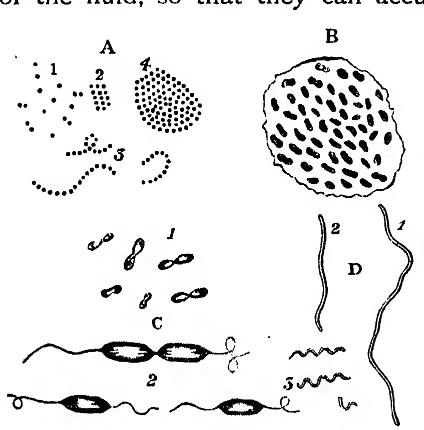


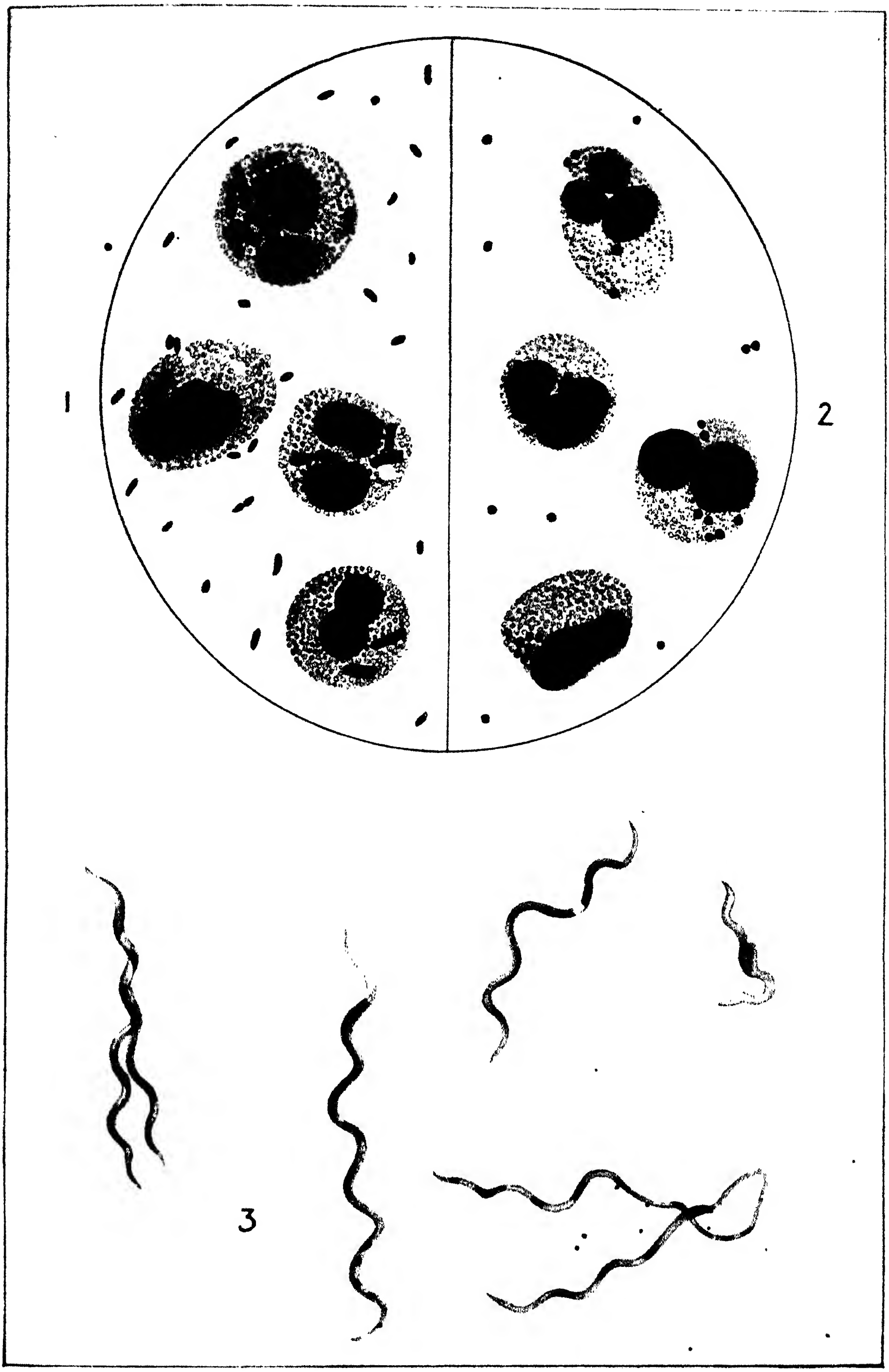
Fig. 432.—Various Species of Micro-organisms

A, Micrococcus: 1, singly; 2, in groups; 3, in chains; 4, in mass. B, a mass of Bacteria (Zoogloea mass). C, Bacilli with rounded ends: 1, singly, constricted in the middle, as about to divide into two; 2, shows, in a much more highly magnified view, the way in which one organism divides into two, each half passing off as an independent form. It also shows the flagella, or lashlike tails. D, 1 and 2, Vibriones; 3, Spirilla. All are very highly magnified to different scales. (After Klein and Dallinger.)

The discovery of this property and of the existence of agglutinins is one of the most recent advances in bacteriology, and one which is now being much used in aiding the diagnosis of disease where the clinical symptoms are doubtful.

DIAGNOSIS OF ENTERIC FEVER.—It was first discovered and used in the case of enteric fever, where in some cases the diagnosis from clinical signs is doubtful and uncertain. The test is here known, after the name of its discoverer, as "WIDAL'S TEST". It is made by mixing the blood serum (*i.e.* essentially the clear fluid part of the blood after clotting has taken place) obtained from the suspected case, suitably diluted, with saline and an emulsion obtained from a broth culture of the *Bacillus typhosus* on a microscope slide. If the blood be from a typhoid case, in a few minutes the typhoid bacilli are no longer found swimming freely about but gathered into distinct clumps of eight, ten, or more individuals in a quiescent state. This is due to the serum of the typhoid patient containing chemical substances noxious to the typhoid bacillus, which are formed in the infected body and are its natural reply to and attempt at protection against the invasion. It is this naturally produced protection which combats the typhoid bacillus and its poisonous products or TOXINS, and by producing an unfavourable nutrient medium sets a termination in favourable cases to the typhoid infection.

ANTI-BODIES.—Similar products are formed and set a natural limitation in definite periods to the course of each particular acute infectious



DESTRUCTION OF MICRO-ORGANISMS BY THE BLOOD CELLS, AND VIEW OF THE ANIMAL PARASITES WHICH CAUSE RELAPSING FEVER

disease caused by bacteria, and lead to recovery when the disease has run its course. In other bacterial infections, and in the diseases caused by protozoa, such as malaria and sleeping sickness (see p. 142), there is not such a definite formation of these chemical protectors, or ANTI-BODIES as they are called, and the organism can go on growing and repeating its life cycle indefinitely in a chronic and recurring fashion, as, for example, in phthisis.

ACTIVE IMMUNITY—OPSONINS.—In the case of many infections, especially those of an acute type, such as nearly all the common acute infectious diseases of our own climate which are accompanied by a rash, and hence known collectively as the EXANTHEMATA, one invasion protects for a long time, or even for life, by conferring what is known as ACTIVE IMMUNITY. This active immunity is undoubtedly chemical in its origin, and probably due to the anti-bodies which are formed in the body as a result of the invasion. It is certain that these anti-bodies are formed by the animal, and there is a certain amount of evidence that the leucocytes take a prominent share in their formation. As we shall see later, the leucocytes are aided in their work by chemical substances dissolved in the plasma or fluid part of the blood; these substances are of quite recent discovery and are termed OPSONINS, or feast-preparers (Gr. *opsōno*, I prepare a feast), from their ability to make the leucocytes take up or ingest injurious organisms.

PHAGOCYTOSIS.—The process of taking up organisms by the leucocytes is known as *phagocytosis*, or eating up of cells, and is particularly carried out by certain kinds of leucocytes, for there are certain distinct classes of these normal protectors of the body. These classes of leucocytes can be recognized by their appearance, particularly after staining with certain aniline dyes, which, moreover, bring out their structure more fully than it can be seen in the living leucocyte, and enable their mode of reproduction to be followed, as well as their classification according to appearance, special dyeing activities, and physiological functions.

The changes of form shown by the same leucocyte at successive short intervals are illustrated in fig. 1 of Plate, FORMS OF ANIMAL CELLS. The ingestion of organisms is seen in figs. 1 and 2 of Plate, DESTRUCTION OF MICRO-ORGANISMS, drawn after fixing the leucocytes by suitable reagents and dyeing with differential stains so as to show in contrast leucocyte and micro-organisms.

The normal leucocytes, stained in order to demonstrate the structure of the cell, and that important part of it known as the nucleus, with its varying forms, and also the varying behaviour to different staining agents, are shown in the top left-hand panel of Plate, DISEASE ORGANISMS FOUND IN THE BLOOD, ETC.

NUTRITION OF AMŒBOID CELLS.—It is only the amœboid cell, with its freely moving semifluid material, which can take in solid nutrient matter by amœboid movement; but even the amœboid cell is also capable of taking in nutrient matter in solution, as we have seen, and, in fact, the more mechanical uptake by amœboid flowing is to a large extent influenced by the chemotactic influence of dissolved substances.

FIXED CELLS

NUTRITION OF FIXED CELLS.—When we come to those cells fixed in shape and position, which form the vast majority in the bulk of the body of the higher animal, we arrive at the conclusion that the nutrition must necessarily be taken up in the soluble form in chemical solution in the nutrient fluid.

NUTRITION OF DISEASE GERMS.—This is also true for the micro-organisms of disease, which are fixed in form in nearly all cases, and hence must take their food in soluble form from the body fluids which constitute a nutrient medium for them, just as they do for the body's own cells.

TOXINS.—Further, it may be added that the organisms of disease produce their injurious effects upon the organism not by their actual mechanical presence, although they may be swarming in the blood or tissues, but by the chemical poisons or *toxins* which they throw out, so perverting the natural nutrient medium for the normal tissue-cells of the host, and setting free in solution excretory products from the bacteria which are soluble and easily permeable to the tissue-cells, into which they pass and pervert the cell's normal chemical processes, and so throw it out of working order.

CONSEQUENCES OF NECESSITY FOR SOLUBLE FOOD.—It is this fundamental necessity for nutriment being presented in soluble form before it can be taken up by most cells, which gives rise to all that subdivision of labour and co-ordination of function which is the characteristic of the higher animal.

NUTRITION.—A considerable portion of our food is in the form of solids or insoluble substances, and even of that portion which is fluid a great deal is presented in forms which cannot be directly utilized by the organism without being at first broken down into simpler forms in the process known as digestion, and then in the processes of absorption and assimilation built up again into new substances more or less specific from one species of animal to another, which can form nutriment properly adapted to the growth of the cells and to the supply of energy for their life processes.

CIRCULATION.—After the nutriment has been prepared and taken up, it must be distributed to all parts of the body, and this introduces the necessity for the circulation of supplies, and the needful oxygen for their combustion and consequent utilization, the requisite mechanism being supplied by the heart and blood-vessels forming the blood vascular system.

RESPIRATION.—The uptake of oxygen for the combustion or oxidation of the food necessitates the provision of the respiratory system, that also serves to remove the carbon dioxide formed as an excretory gaseous body by the oxidation.

NITROGENOUS EXCRETION.—Other excretory substances which are not gaseous must be removed in solution, such as urea and uric acid, and for this purpose the renal system is developed, which keeps down the

percentage of these substances in the circulating blood and prevents the tissue-cells from being poisoned by them.

Supports and Protection—Locomotion.—The animal must have stability of shape and protection from injury provided for the delicately organized soft tissues, and must be able to move about in search of food and to carry out the other processes of its life, and for this purpose there arise the jointed skeletal system of bones and the muscles or engines for manipulating them.

Co-ordination and Control.—Further, there must be co-ordination and control of all these different systems, and this office is discharged by the nerve-cells and nerve-fibres which constitute the nervous system.

Specialized Cells not Limited to One Function.—It must not be thought that in this extreme specialization of function, which divides the cells into distinct classes in the higher animal, there are lost those more fundamental and essential properties which we have described as existing in the case of the unicellular amœboid cell; on the contrary, the especial skilled labour, so to speak, of the higher cell is taken on in addition to them, whereby, in addition to work performed entirely on its own behalf, it discharges a special type of activity on behalf of the community of cells of which it is a citizen.

Saving the one exception that the fixed cell cannot by amœboid movement take in and digest solid particles, but must have its nutriment brought to it in a specially prepared form in the fluid or lymph which bathes it, derived from the fluid part of the blood (plasma), the cell of the higher animal carries on all the elementary life functions seen in the free-living amœba.

Thus, it digests the soluble food which it absorbs, takes energy from it, elaborates from it as in a little microcosmic laboratory chemical products useful to itself, which it retains and utilizes for building up itself and repairing its waste or supplying it with energy, sends out into the lymph other chemical products essential to the life and work of other classes of cells existing in the body with it and performing different species of labour for the general good, and in addition it forms, just like the amœba, waste chemical products which must be carried away and excreted.

Like the amœba, the cell of the higher animal requires oxygen for its work, and, like it, takes this oxygen up from the fluid medium in which it is immersed, and similarly gives up excreted carbon dioxide to the medium; but the conditions are such in the higher animal that the medium must be renewed and refreshed all the time, and this is carried out by the systems of cells to which allusion has been made above.

Division of Labour.—The relative work of the unicellular organism and of the specially organized cell of the higher animal may be well illustrated by an analogy with the life of the savage and that of the inhabitant of a civilized state. Thus, both the savage and the civilized man must eat in order to live, and the same elementary functions must be carried out in the body of each just as is the case in our two types of cells. But while all savages carry out the same type of labour in searching for and preparing their own food, and the occupation of one is the same as that of

another, as civilization advances the especial work of one man or set of men in the community becomes more and more differentiated from that of another, the members of one profession render one type of service, and those of another profession an essentially different type.

So in the highly organized body one set of cells takes on one function and another set a different function, and as development proceeds, and more elaborate needs are felt for further progress, more and more specialization takes place.

ADVANTAGES AND DISADVANTAGES OF SPECIALIZATION.—Not only does this specialization present great advantages, it is entirely indispensable to a high state of organization and perfection of co-ordination in either the individual body or in the community of civilized man; but, like all advantages, it carries corresponding disadvantages which must not be lost sight of, and which can never be entirely removed, although they can be minimized—in the state by concerted and timely action, and in the body by a proper understanding of how they occur, and like timely action in combating them by removing the cause if possible, or counteracting by an anti-movement from without.

Thus, on account of the highly specialized labour of the community, a strike of one set of workers, or a stagnation of production from natural causes, often leads to disastrous results for the whole community. Similarly, in the body of the highly organized animal a disorganization of function of one set of cells, either from natural organic causes inherent in the body or from their invasion by disease-producing organisms or other accidental cause, leads invariably to general discomfort and depreciation of function in other sets of cells, and the whole body suffers. If the loss of function is complete or permanent, death is usually the result, although the set of cells affected originally may form a very small and specialized group. Special examples of this we shall see later in dealing with the modern knowledge which has been acquired regarding those chemical products of cell-activity known as INTERNAL SECRETIONS furnished by certain glands, the functions of which long remained obscure.

COMMON CHARACTERS OF CELLS.—For the purpose of carrying out this division and co-ordination of labour it becomes necessary that the cell should be greatly varied both in the chemical composition and organization of its contents, and in its structure and form, but certain general characteristics are always preserved. Thus the material of the cell is always so constituted that it gives the well-marked chemical tests for the class of substances known as PROTEINS, although in finer details of chemical structure these proteins differ from one form of cell to another. In microscopic structure, again, the various cells present at the same time general similarities, accompanied by finer differences undoubtedly related to differences in character of work. Thus the general plan of structure of what is known as the CYTOPLASM, that is, the cell material or protoplasm forming the part of the cell surrounding the portion called the *nucleus* (see the Plates showing the PROCESS OF MITOSIS), is that of a network or foam-like structure, which at times, on account of slight changes in the constituent granules, comes to take the appearance of a finely or coarsely granular

structure (see the leucocytes in figs. 1 and 2 on Plate, DESTRUCTION OF MICRO-ORGANISMS), or if there be a parallel arrangement, as in many nerve-cells and fibres, gives a fibrillar appearance of parallel-running fine lines or fibrils.

THE NUCLEUS

The NUCLEUS is an important structure present in all active cells of higher animals, and of which traces have recently been demonstrated in the bacteria, in which it was formerly supposed not to exist. Further, in certain cases where it was supposed to be absent, its absence has been shown to be due to degenerative changes, as in the more superficial layers of the epidermis. A functional disappearance of the nucleus is seen in the red blood corpuscles of mammals; but here, as in other instances where the nucleus is absent, it has been shown that at an earlier stage, in which the cell is more active physiologically, and actively reproducing itself, a nucleus is present. The nucleus disappears in some manner later, and the function of the cell becomes restricted to the simple chemical one of acting as a carrier of oxygen to the tissues, a function to which it is better adapted without a nucleus. This cell then takes the form of a thin biconcave disc, which is the most perfectly adapted form that can be conceived for the uptake of oxygen or other dissolved substance from the fluid in which it is immersed. This shape is the last stage in a process of adaptive evolution, and gives the largest surface per unit of volume compatible with stability of form. The thickened edge gives a stable form by conferring resilience, so that the red blood corpuscle does not fold on itself and remain doubled up as a plane disc would, while the thin centre gives a maximum surface for absorbing the oxygen. This is one of the most beautiful examples which could be quoted of adaptation of the form of the cell to the work which it has to perform. Other examples are seen in the nerve-cell and its long process in the nerve-fibre, the intestinal villus and its lining cells, and the cylinder of the contracting muscle fibre (see Plate, FORMS OF ANIMAL CELLS).

FORM OF NUCLEUS.—Returning to the cell nucleus, we see that all cells either possess a nucleus or did possess one at an earlier period in their history. This nucleus, like the cell itself, takes many different forms (see Plate, FORMS OF ANIMAL CELLS); thus it is spheroidal or ellipsoidal in the majority of cases, but it may be rod-shaped, as in the muscular fibres which regulate the bore of the small blood-vessels, the intestine, and other tubes and hollow organs in the body, or it may be very irregular in shape, as in the case of certain of the leucocytes.

IMPORTANCE OF NUCLEUS.—Whatever may be the form of the nucleus it is a most essential element in the cell, and at certain stages presides over its life functions in a most remarkable way. Of further interest to us is the fact that the properties of the nucleus change in certain conditions of disease so as to interfere with the normally regulated life of the cell, and cause that over-excessive production of cells which gives rise to tumours, and notably malignant tumours or cancers.

It is possible by mechanical means to divide a living cell into two parts, one of which contains the nucleus while the other does not. This has been specially studied in unicellular organisms, where it is found that the part which contains no nucleus may live for some time, move about by means of cilia or other locomotive appendages it may possess, and also take up particles and carry out processes of nutrition, but in a longer or shorter period it invariably ceases to exist, never having evolved a complete organism with a new nucleus, and never having divided to form two new organisms. On the other hand, the portion containing the nucleus, even though it possesses but a small portion of extra-nuclear protoplasm, or cytoplasm as it is called, not only continues to live, but in many cases, by the reproduction of the parts cut off, forms a new complete cell or organism like the original, which may proceed to divide and form two new organisms in a normal fashion. Similar changes undoubtedly occur in multicellular organisms, and prove the essential part played by the nucleus in the complete life of the cell.

THE NUCLEUS IN CELL-DIVISION.—While it is thus essential for the complete exhibition of living properties in the active cell, it is, however, in the process of cell-division or reproduction that the nucleus becomes particularly in evidence, and it may be said to initiate and control the whole of this wonderful and interesting process. This department of cytology has in recent years attracted great attention. Much advance has been made in it, and the literature of the subject has become enormous. Quite recently the aspects of the subject related to pathology have shown great development, since it has been shown that in many pathological processes, and particularly in malignant growths, there is a tendency to revert from the usual type of cell production seen in later stages of growth, development, and repair of the body to a quite distinct type seen in the very first division of the nucleus of the ovum and spermatozoon previous to fertilization by the union of these two nuclei. This would give the important indication, or at least suggest the hypothesis, that in such pathological growths the tissue-cells are tending to become senile, and attempting to rejuvenate in the manner which has been stated above to be necessary at intervals in the case of unicellular organisms.

Whatever may be the explanation of this reversion to the sexual mode of division, or MEIOTIC PHASE (Gr. *meiosis*, a reduction) as it has been termed in pathological division, the whole subject of nuclear division as a preliminary to cell reproduction is so fascinating, from its intimate relationship to the life of the cell, where the ultimate secrets of biology lie hidden, that a short account of the main features of the reproduction of cells may here be given.[1] These changes are illustrated in the accompanying two plates, of which one represents cell-division in ordinary tissue-cells, while the other one shows the changes in the meiotic phase which precedes (*a*) the formation of the spermatozoon or male reproductive cell in the testes, and (*b*) the so-called maturation of the ovum after

[1] A recent and full account of this and other important problems of cytology is contained in *The Essentials of Cytology*, by C. E. Walker; London: Constable & Co.; from which plates have been taken by kind permission of the author and publishers.

it has been shed from the ovary, and before it can be fertilized by the nucleus of the spermatozoon or male pro-nucleus. As stated above, this meiotic phase, or a form of division closely resembling it, is frequently seen in the division of cancer-cells which proceeds so rapidly in malignant growths.

KINDS OF CELL-DIVISION.—It may be mentioned as a preliminary that there are two forms of nuclear division, in one of which there is simply an hourglass-like constriction of the nucleus, which then divides into two portions; and, the remainder of the cell protoplasm similarly constricting and dividing, there are formed two daughter cells. This type of division is spoken of as simple or amitotic division, or as AMITOSIS (Gr. *a*, without; *mitos*, a thread). The other form of division involves much more complicated changes in the nucleus, and the whole process is described as MITOSIS or mitotic division.

ORDINARY MITOSIS.—The type of mitotic division which occurs in the ordinary processes of reproduction of tissue-cells in SOMATIC OR VEGETATIVE DIVISION, as it is called, is simpler in character and will be described first, although in the life-history of the animal it occurs after the meiotic division, which is the first stage in the process of reproduction of the higher animal.

In order to obtain views of the changes in dividing nuclei as shown in the plates, the tissue selected must be one in which growth is proceeding, and it must be obtained from the animal immediately after death, and *at once* fixed *in statu quo* by a rapid fixative, that is, a solution containing chemicals causing almost instant death to cells by combining with their protoplasm. Further, the reagents chosen must have good penetrating power, and the pieces of tissue chosen for fixing must be small, with the same object in view, namely that of instantly killing and fixing the cell structures.

If this be not done, very few cells will be found in a state of active nuclear division, and many of the intermediate stages will be lost. The reason for this is that all the cells in the different tissues of the body, as shown by physiological tests, live for a varying time after the death of the animal. The nerve-cells are the first to die, and show little in the way of vital properties within an hour after death, although their processes in the nerve-fibres remain irritable for some hours longer; the cells which retain vitality longest are those of the skin and hairs, which show signs of life for as long as a week after death, and hairs may grow for two or three days after the death of the animal. It may be pointed out that this greater longevity of skin after death is of great importance in the operation of skin-grafting in preserving the cells until a new blood supply carrying nutriment can be developed from the host on which the grafting has been carried out. It is also of great service in the experimental grafting of tumours for purposes of study in cancer research.

In the study of nuclear division this continuation of tissue-life is, however, a disadvantage, because on killing the animal the nutrition of the cells is cut off or altered, and as a result the cells, with what remaining vitality they possess, pass rapidly into the resting condition (drawn

in No. 1 of Plate showing MITOSIS). Hence, as stated above, they must be fixed as instantaneously as possible immediately after the death of the animal. The best reagents for this purpose are different preparations of osmic acid, chromic acid, and glacial acetic acid, the exact composition of which may be found in practical books on histology.

The resting state of the cell is shown in fig. 1 of the double Plate on MITOSIS. It may be seen that there is a reticulate arrangement in both the cytoplasm and the nucleus, the network being much coarser in the case of the nucleus, and tending to form thicker masses with connecting processes which stain much more darkly with the appropriate nuclear stains. This darkly staining nuclear material is known as CHROMATIN because of this staining property (Gr. *chrōma*, colour). It differs chemically from the material of the *cytoplasm* (or extra-nuclear part of the cell) in containing a much higher percentage of phosphorus — the phosphorus-containing bodies are known as NUCLEO-PROTEIN, from their occurrence in this situation, and are most important in the life of the cell. In their chemical nature they are organic acids, containing a series of acids known as the NUCLEIC ACIDS, which have the property of combining readily with the stains known as nuclear stains, and hence conveniently mark out in cytological work the important changes which occur in the chromatin during cell division. It should also be noted in this figure that the nucleus is marked off and separated from the cytoplasm by a membrane which disappears when the cell advances in the process of division (compare fig. 4). Attention may also be drawn in fig. 1 to two small darkly stained dots (shown above the nucleus in the figure), surrounded by a more finely granular area; these dots represent the CENTROSOMES, which afterwards separate and regulate the process of division, forming as it were the two poles of the division figure or spindle (compare figs. 5, 7, 11, and 12). The two dots or centrosomes, with the surrounding area which later becomes clear of granules, are often spoken of as the ATTRACTION SPHERE.

Passing to fig. 2, we observe that the first change which occurs in the nuclear material is that the deeply staining chromatin, instead of forming a network, takes on the appearance of a convoluted or coiled-up long thread or SPIREME, which often has a double-beaded appearance, as if it consisted of two long rows of granules placed side by side, and connected by fine threads of the chromatin material. It may further be observed that the two centrosomes have commenced to move apart, and that in connection with them there has developed an exceedingly fine fibrillar arrangement known as the SPINDLE and ASTERS. The fibrils of the spindle are very much more slender than the fibres of chromatin in the nuclear spireme, and are only seen by delicate focusing and careful manipulation of the light under a high microscopic power. The spindle arrangement bears a curious resemblance to the lines of force as marked out in direction by iron powder in the magnetic field between the poles of a magnet, the two centrosomes representing the magnetic poles. Thus, some threads of the spindle run almost from the one centrosome to the other, save for a small clear space immediately surrounding each

centrosome, while others, just like the fine filings in a magnetic field, pass out in a radiating fashion into the surrounding cytoplasm, thus forming the two asters.

The next conspicuous change, and one of the most interesting and probably most fundamental in the whole process, is the *transverse* division of the chromatin spireme of the nucleus into a very definite and specific number of lengths, as shown in fig. 3. These shorter lengths of the chromatin thread are known as CHROMOSOMES, and throughout the rest of our description we shall have to use this term constantly.

One of the most wonderful things about the whole beautiful and complicated process of cell division is that the *number* of these lengths or chromosomes is absolutely fixed and invariable (in any given species of animal or plant) for all the dividing cells in the process of growth of the animal or plant, and is *always* an even number. In the case of the first nuclear division of the sexual cell (spermatozoon or ovum) only is the number halved, and the complete full number required for all the many thousands of subsequent divisions in the development and growth of the animal or plant is again restored when the nuclei of the male cell and female cell have united. We shall have to revert to this point later in considering this first nuclear division and the cancer-cell division, which are alike in this respect.

Many theories have been put forward as to the objects fulfilled in the cell by this division into the chromosomes, and their halving in number at the commencement of development, and volumes have been written about the subject in connection with heredity and the transmission of hereditary properties unsullied or untainted by the individual life from generation to generation. Apart from such theories we can only marvel at the operation of this natural law, which divides the microscopic thread of the spireme of the nucleus into such a definite number of lengths, reunites these gradually into a network, where they are apparently inextricably blended, as in the parent cell, then forms once more a thread and rescues cosmos out of the apparent chaos, and with unfailing accuracy gives the same number of chromosomes. This process is repeated through almost countless generations of cells, until from the first complete cell fertilized by union of male and female nuclei there is evolved in ordered process an adult animal. Throughout the process of development cells of the most varied forms (see Plate, FORMS OF ANIMAL CELLS) and diverse physiological functions arise, but the principle of the fixed number of chromosomes is always preserved inviolate for every type of cell in the whole body, saving the one exception of the primary division of the sexual cells.

The number of the chromosomes varies from two in the case of certain parasitic worms to over a hundred in a few cases. In man and in the mammalia generally the number is sixteen.

Returning to fig. 3, we observe that at first the spindle-fibres curve past the nucleus, the threads having lengthened as the centrosomes have moved more apart to form the two poles of the spindle, and the nuclear membrane is still intact.

In the next two illustrations (figs. 4 and 5), which should be studied together, are seen two views of the arrangement of chromosomes and spindles at a later stage; the nuclear membrane has disappeared and the spindle has arranged itself symmetrically with regard to the chromosomes. In these two figures No. 4 shows a longitudinal or polar view of the spindle and No. 5 an equatorial view. It is to be observed that the chromosomes have become arranged on the fine threads of the spindle. In fig. 6 a further chapter in the history is depicted; the chromosomes were previously formed by a cross cutting or division of the spireme thread, now each portion or chromosome splits *longitudinally*, the splitting proceeding as shown from the middle of the length of each now double thread towards the two ends, as if there was an equal pull from each pole or centrosome (figs. 8 and 9). As seen in the next illustration (fig. 10), the split chromosomes now travel along the sets of spindle fibrils towards the two centrosomes, these threads appearing to act as carriers, but not shortening in the process, for they still extend down to the equator, as shown in the figure. In this figure we have a representation of one of the most frequent and striking appearances seen in dividing cells, and known as the DI-ASTER or DOUBLE STAR; the frequency of its appearance in sections of cells shows that it is one of the longest stages in point of time in the process. It may be pointed out that by this longitudinal splitting an equal distribution, both in amount of chromatin material and number of chromosomes, is secured between the two daughter-cells, and that a portion of chromatin from each individual chromosome passes into each of the two new nuclei for the two daughter-cells.

It is at this di-aster stage that the division of the cytoplasm usually commences by the mass taking on an hourglass shape by constriction at the middle, as seen in fig. 11, which goes on to completion as illustrated by figs. 12 and 13. After the sets of daughter chromosomes have reached the two poles, there commence a series of retrogressive changes, illustrated in figs. 12 and 13, back to the resting condition of the nucleus. These changes are practically an inversion of those described as characteristic of the opening changes in nuclear division. Thus there is a loss of identity of the chromosomes, but the spireme stage is not so marked as in the case of the nucleus commencing to divide; at about this stage the centrosome divides into two to be ready for the next division, and the remains of the aster disappear; finally, the internuclear portion of the spindle disappears as the division line in the cytoplasm becomes complete, and the irregular reticular formation of the fibrils, which is characteristic of the resting cell, becomes evident in both cytoplasm and nucleus.

MEIOTIC NUCLEAR DIVISION.—We may now turn to that form of nuclear division which has been variously styled as reproductive, heterotypical, and more recently as MEIOTIC. The latter name is preferable, because only the first of the two maturation divisions, which the nucleus of the ovum undergoes previous to fertilization, is carried out under this type. The second one belongs to the ordinary somatic type, with, however, only half the usual number of chromosomes characteristic of the species, the number having been reduced in the first division. The

term heterotypical is objectionable, though sanctioned by usage, since it betokens something pathological, or departing from a type, and this form at this particular stage in the development is usual and normal.

At an early stage in the development of the young animal certain cells become clearly marked off and segregated together to form a reproductive organ, which at a certain age begins to develop those cells known as reproductive cells by which the species is later to be propagated. This organ is called the testis in the male and the ovary in the female, while the reproductive cells of the first form are known as spermatogonia in the male and as oögonia in the female.

The subsequent history of these two types of cells is very much alike up to the period at which by the union of an *equal* portion of nuclear matter from each the nucleus of the fertilized ovum is formed.

It is with this very interesting portion of cell-history that we are at present concerned, and we shall base our description chiefly on that of the female cell, pointing out the essential differences in the male, and leaving it to be understood that the two closely similar sets of development are elsewhere identical.

The small set of cells set apart for reproduction in either sex, at first, in the early life-history of the animal, increase in number by ordinary division, as sketched out above, so that each original cell forms a number of descendants which are the immediate predecessors (*a*) of the ovarian egg previous to maturation and fertilization in the female, and (*b*) of the spermatocyte or grandfather cell of the spermatozoon in the male. Then ensues a long period of rest in both sexes. During this period the ovum, surrounded by its membrane, is contained in a special cavity bordered by a nutrient capsule or envelope of cells which is known as the GRAAFIAN FOLLICLE, while the spermatocyte forms a large cell in the testis. In each case there must come, when sexual activity commences, a period of two cell-generations, and it is the first of these which differs from all others and has to be considered in detail. The natural result of these two generations is the formation of four granddaughter cells in each case. The only essential difference in the two sexes is that in the male the cytoplasm is equally distributed, and all four cells become equal and functionally active spermatozoa or sperm cells capable of fertilizing ova; whereas in the case of the female only one of the four cells remains as an active ovum which retains practically all of the cytoplasm, the other three being left derelict as functionless nuclear remains which are called POLAR BODIES. The four cells formed by the two divisions of the male cell are at first termed SPERMATIDS; the spermatids form in their subsequent growth a long flagellum or tail by means of which they are able to swim rapidly about. A chemical attraction exists between them and the ovum, and they swim up to and surround it. After a time one of them pierces the ovum, after which the tail disappears, and the sperm nucleus belonging to this spermatozoon unites with the ovarian nucleus which has by a pair of similar previous divisions been prepared for the union.

In the case of the ovum the two divisions usually take place after it has been shed from the ovary, and in many cases do not commence until

after it has been penetrated by the head of the spermatozoon containing the nucleus. The shedding of the ovum is preceded by the ripening of the Graafian follicle. The surrounding layer of cells secretes a fluid which enlarges the cavity in which the ovum is contained, and by this increased growth the follicle is made to come at one part to the surface of the ovary, and, as the process goes on, to swell out from the surface. The wall of the cavity, as the distension goes on, becomes thinner and thinner, and at the same time the ovum becomes detached and floats loosely in the fluid of the cavity, usually with a few of the nutrient cells attached. At length the wall of the follicle bursts, and the ovum is shot out with the contained fluid. It is in the first maturation division in both the male and female reproductive cell that the reduction by halving of the number of chromosomes occurs in the peculiar manner which we shall now proceed to describe, having cleared the ground by these preliminary observations.

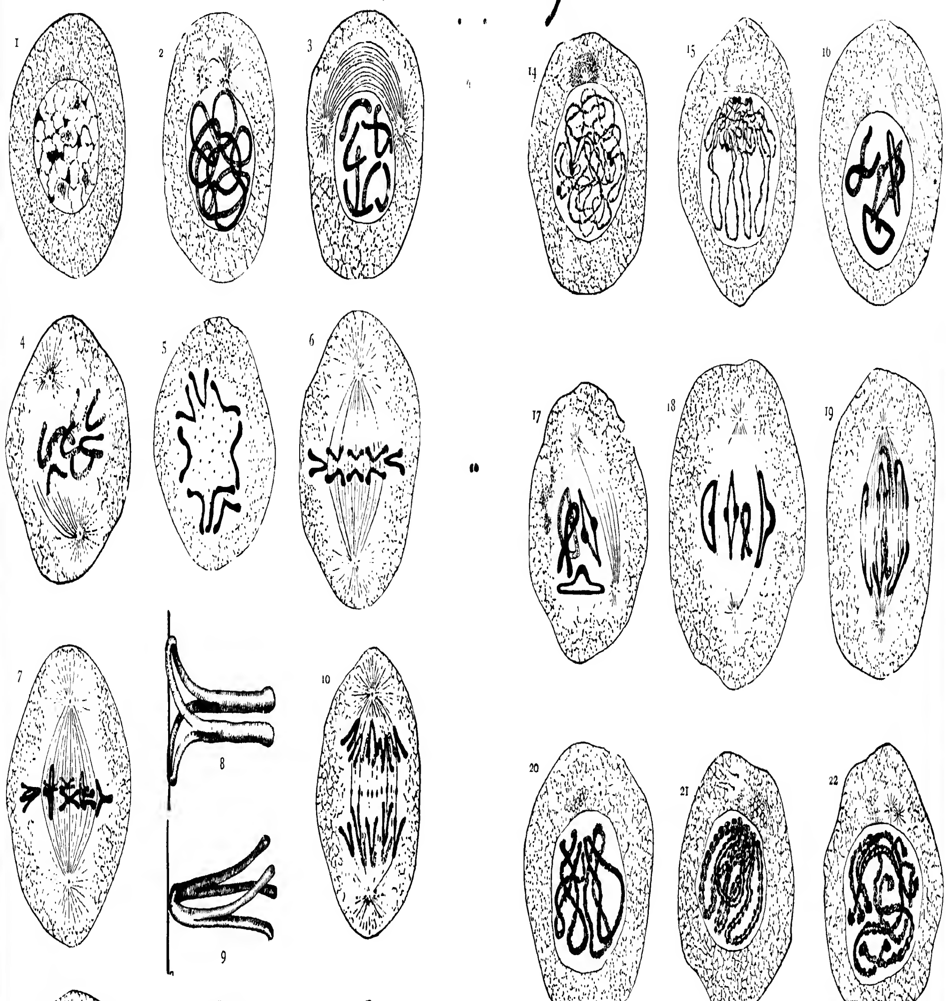
The changes which the nucleus undergoes are illustrated by figs. 14–22 of the Plate on MITOSIS. A general comparison of these with the figures of the preceding plate, representing ordinary cell-division, is sufficient to show how different the two processes are. In the first place the spireme thread formed is much longer and finer (fig. 14); this then contracts in a peculiar manner, an interesting stage of which is seen in fig. 15, into a shorter spireme with coarser threads, and this then breaks across into a number of chromosomes (see fig. 16), and it is significant that the number of these is exactly *half* of that formed in the ordinary nuclear divisions of the species whatever that number may be.

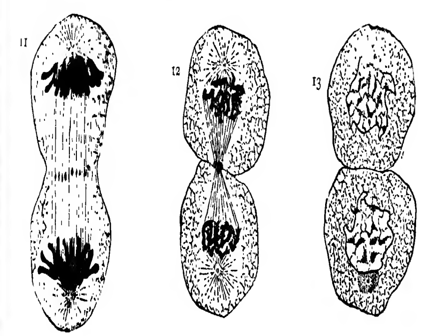
The form of these chromosomes is also different from that of the ordinary or somatic chromosomes, and varies greatly in different species, forming rings in some, in others groups of four small bodies called *tetrads*, united by finer threads to form also rings, while in others, such as the mammalia (illustrated in the Plate, figs. 16 and 17), we find convoluted loops twisted upon themselves, and longer than the somatic chromosomes. It should also be noted as a distinctive feature of this form of nuclear division that the centrosomes leave their original position, and that the granular material originally surrounding them becomes vesiculated and finally disappears.

The next observable fact (shown in fig. 17) is that the chromosome loops become double-beaded, and separate longitudinally to form what are termed GEMINI; these gemini now separate on the spindle, as in the preceding type of division, and travel to the two poles. In the case of the ovum there is no following equal division of the cytoplasm, but the half of the nucleus with a small amount of cytoplasm is extruded from the cell to form the first polar body.

This extruded polar body in some cases never divides again; in other cases it divides once.

After a short resting period the seminucleus again divides in the second maturation division, but this time following the method of ordinary division, and without further diminution in the number of chromosomes. Thus finally we are left with one-quarter the original chromatin and





Ordinary Division in the Growing Animal.—1. A cell with the nucleus in the vegetative condition. . Early prophase of division. The linin and chromatin have adopted the form of a coiled-up thread (spireme). The asters and spindle are forming in connection with the centrosomes 3. The spireme has broken up into the chromosomes, and the spindle is in a more advanced stage of formation. 4. The nuclear membrane has disappeared The spindle is fully formed. 5. Each of the chromosomes has become attached to a spindle fibre. Metaphase. (Polar view.) Metaphase. (Lateral view.) 7. The chromosomes are splitting lengthwise. 8, 9 The different ways in which the chromosomes split. 10. The halves of the chromosomes are travelling towards the opposite poles of the spindle. Early anaphase.) 11. Later stage of anaphase. 12. The daughter cells are separated from each other. (Tel phase.) 13. The reconstruction of the daughter nuclei.

Reproductive Division at the Outset of an Individual Life.—14. The early fine spireme 15. The first synaptic contraction figure. 16 The meiotic gemini formed. 17 The nuclear membrane has disappeared. 18. The gemini attached to the spindle fibres. 19 Separation of the meiotic gemini. In vertebrates and in many other animals the changes are as follows: 20. Loops are thickened The centrosomes leave the archoplasm. The archoplasmic vesicles appear. 21. The loops show double beading. Minute flagellæ grow from the centrosomes. 22. The loops spread out.

SEMI-DIAGRAMMATIC REPRESENTATION OF THE PROCESS OF MITOSIS IN A CELL EXHIBITING 8 CHROMOSOMES

one-half the normal number of chromosomes in the remaining portion of the nucleus of the ovum ready for fertilization. Fertilization occurs by the male and female nuclei approaching each other, forming an ordinary nuclear-division figure, and dividing, accompanied by equal division of the remainder of the cell, so that two equal cells are formed. This process occurs again in a direction transverse to the first, giving four cells, which again yield eight, and so the process is repeated by which the organism becomes fully launched on the lengthy process of reproduction, the details of which cannot here be followed out to their conclusion.

MALIGNANT GROWTHS.—The chief interest to us in following out in detail this meiotic type of division characteristic of the first reproductive

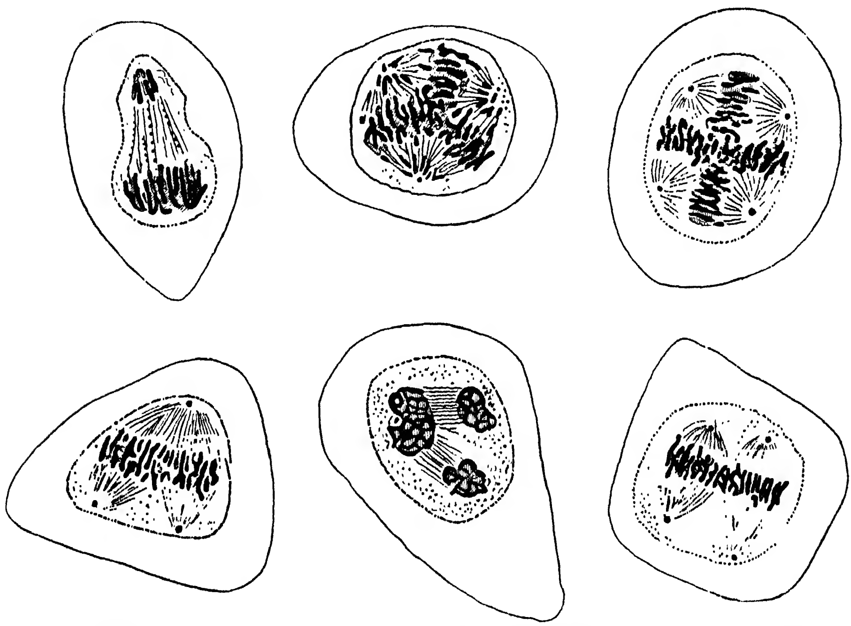


Fig. 433.—Irregular Nuclear Divisions in Human Cancer Cells (after Galleotti). The figures show irregular and unequal division of the chromatin, and also division in progress from more than two centres.

division is that it has recently been shown to occur in those insurrectionary cells of the body which characterize malignant growth. The tumour cells, having as it were revolted from the fixed laws of the commonwealth of cells to which they belong, have resorted to an unbridled process of reproduction possessing many of the characteristics of this distinctively sexual type. Once started upon this process a luxuriant over-production goes on, and the new abnormal tissue invades and destroys the normal tissue, the abnormal cells make their appearance in new situations, called METASTATIC GROWTHS, in different organs. As the new material at each situation increases in size, it cuts off or diminishes its own blood supply, particularly to the central parts, and these break down, degenerate, and throw out poisonous substances into the circulation. As a result the

general health breaks down, there is great wasting of the tissues, and that general condition known as cachexia, and finally death ensues either from this general effect, from erosion of vital parts, or from mechanical interference with some vital region.

In addition to this reversion in nuclear division there are other peculiarities of division of the nucleus often seen in cancer-cells, which show a perversion of function similar to that which can be induced by variations in cell nutrition, especially in the early history of reproduction; these variations are collectively spoken of as pathological cell-division, or pathological mitosis.

ABNORMAL MITOSIS.—The two chief forms of abnormal mitosis are (1) ASYMMETRICAL MITOSIS, in which the chromosomes are distributed in unequal number to the daughter-cells, and (2) MULTIPOLAR MITOSIS, in which the number of centrosomes is more than two, so that multipolar instead of bi-polar spindles are formed. These changes in cancer cells

Fig. 434.—Pathological Nuclear Divisions similar to those shown for Cancer Cells, induced by treatment with antipyrin and quinine. (After Galleotti.)

are illustrated in fig. 433, and are accountable for many of the remarkable variations seen in dividing cancer-cells in the number of chromosomes.

It is most interesting that similar changes in nuclear division can be induced by the presence of certain poisons in the circulation, such as antipyrine, cocaine, and quinine (see fig. 434). It has been shown recently that an increase in alkalinity has the power of inducing such pathological mitosis in the early stages of division of the eggs of the edible sea-urchin (*Echinus esculentus*), and also that there is an increased alkalinity in the blood of cancer patients. Such evidence would tend to point out that cancer may originate from chemical irritation and corresponding stimulation to division of the cells, and if the nature of such irritant bodies and the mode of their origin could be discovered, we ought here to have an interesting clue for further study of cancer production, and eventually of its control.

CHAPTER III

TISSUES

DIFFERENT FORMS OF CELL.—In the further processes of development the cells of the higher animal take on many and widely varied forms according to their specialized work in the organism. Some examples of such varying forms are seen in the illustrations given in the Plate, FORMS OF ANIMAL CELLS, and a general survey of the figure gives an excellent impression of change of form with change of function. The first figure illustrates the many kaleidoscopic changes which the leucocyte can successively undergo, and makes a sharp contrast with the fixed spherical form of the ovum (fig. 2) with its limiting membrane, spherical nucleus also fixed in shape, and nutrient granules in its cytoplasm. The third figure shows ciliated epithelium cells scraped from the windpipe, with rows of fine cilia, which by their wavelike concerted motion drive fluid and particles in contact with them over the mucous surface, from which they project, in a determinate direction. For example, such ciliated cells clothing the respiratory passages impel the moistening fluid upwards from the lungs towards the throat and gullet, and in this way prevent to a large extent the respiratory system from being infected by disease germs borne in with the inspired air, or from getting choked by particles, which in the course of a lifetime in cities would more than entirely fill the lungs with dust and coal smut. In spite of this protection the lungs of city dwellers, as age advances, become black from absorbed particles, and the lymphatic glands at their base hard and gritty. Fig. 5 shows a type of cell called a GOBLET CELL, that affords an example of the simplest, one-celled secreting gland, which pours out moistening mucus on many mucous passages, as in the windpipe and in the large intestine (compare with the more complicated gland from the stomach wall shown in fig. 13). In fig. 4 is drawn a flattened type of cell such as is seen in a scraping taken by a blunt knife from the mouth, and forming the upper layers of stratified epithelium, such as is shown in cross section in fig. 6. Notice in the latter figure the columnar shape in the deeper layers passing into the scaly or flattened cells in the upper layers. The polyhedral cells of a soft gland, such as the liver, are shown in fig. 7 with passages for secretion between them; the shape is here due to mutual pressure on all sides.

The next three figures (8, 9, 10) represent different forms taken on by cells of the muscular system. In fig. 8 a column of voluntary or skeletal muscle is shown surrounded by its delicate sheath, only marked by its elongated oval nuclei. On receiving a nerve impulse, it broadens and shortens without changing in volume, and thus the muscle as a whole shortens, and corresponding movements occur. The voluntary muscle column is probably formed by the fusion together of a large number of cells. In heart-muscle, which is of course not directly under the control of the will in its physiological activity, the individual cells remain distinct

and are short, squat cylindrical masses, abutting end to end, as shown in fig. 9. In fig. 10, a muscle fibre from the wall of the intestine is shown; such fibres are called *involuntary* muscle fibres, and are of wide distribution in the body. Muscle fibres of this kind are present in all the tubular arrangements, such as the alimentary canal from about the middle of the gullet or œsophagus onwards, in the vascular system, in the tubes of the reproductive system in both sexes, and the walls of the uterus, in the respiratory system, and in the urinary or renal system. They are disposed both longitudinally and circularly, and can alter the length, and also the calibre, of the tubes, according to their degree of tonicity or chronic state of contraction.

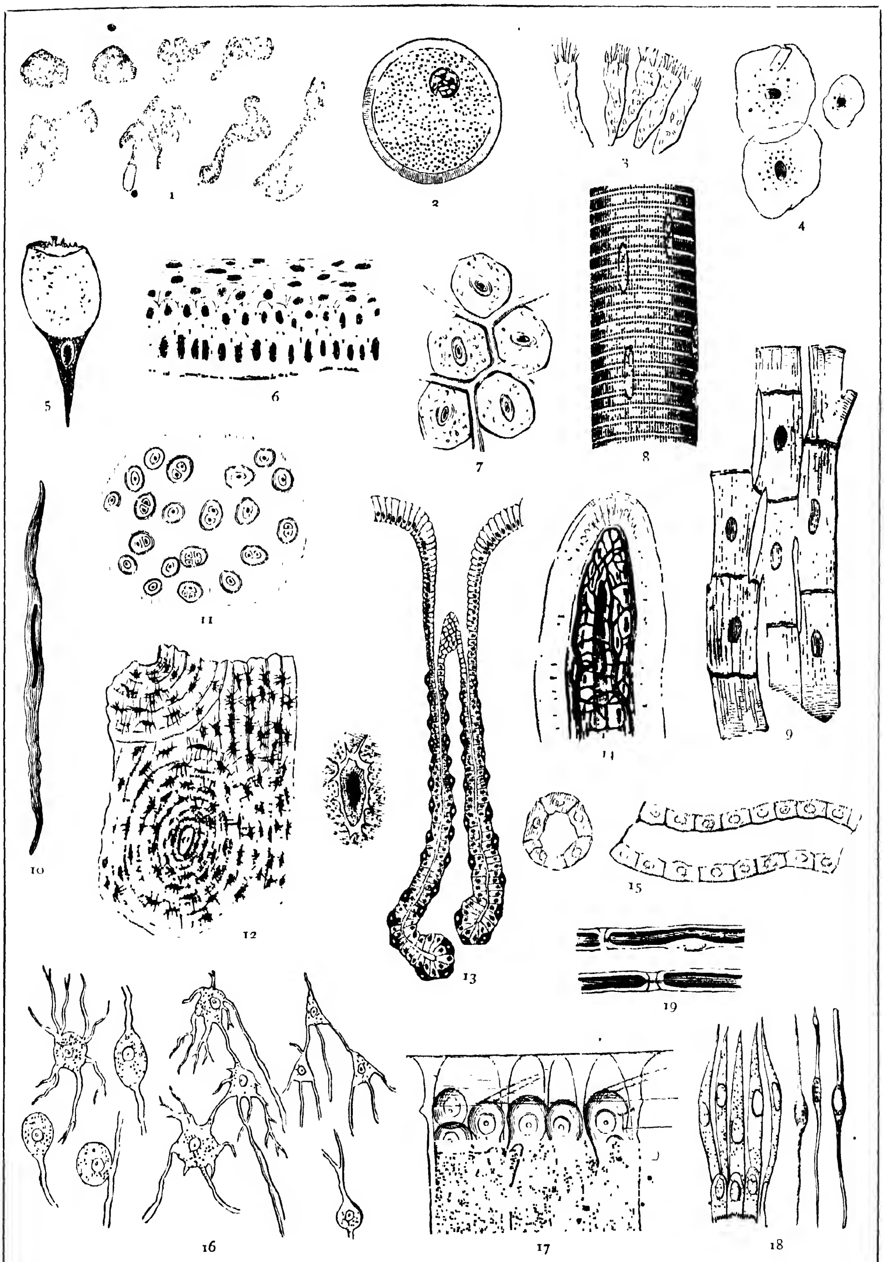
TONICITY OF MUSCLE FIBRES.—This tonicity is regulated in two chief ways—(*a*) by a chemical substance secreted by certain glands (see p. 122), and (*b*) by impulses sent to them by a portion of the nervous system not under the control of the will in any direct fashion, which is called the SYMPATHETIC NERVOUS SYSTEM. This sympathetic system is always in action in varying degree, and regulates the unceasing physiological activity of many of those most important and necessary processes which proceed entirely apart from our cognizance both in waking and sleeping hours. Thus, the activity of the many secreting glands is organized and controlled, and the many varying activities of cell-life regulated to a nicety according to the wants of the body. One of the most important departments of such control by this AUTONOMIC or self-governing nervous system as it is also called from its automatic action, is that exercised by the sympathetic nerve fibres passing to the involuntary muscular system. Thus, by contraction waves, termed PERISTALTIC CONTRACTIONS, the food is moved along the alimentary tube as it undergoes digestion. Similarly, the secreted urine is moved along the tubes called ureters from the kidneys, where it is *continuously* secreted, to the urinary bladder, where it can be stored until it can be conveniently voided. In like fashion the bile is caused to flow and is stored in the gall-bladder till it is wanted in digestion, and again onwards from that receptacle to the intestine, where intestinal digestion and absorption are in progress. There is similar movement, produced in like fashion, of the other secretions. Again, by the degree of tonicity of the small twigs of the arteries, known as ARTERIOLES, the supply of blood to different organs is controlled according to their needs from time to time; and when an organ is more active it is supplied with more blood, by a decrease of the tonicity or degree of contraction, so giving vessels of wider bore, and conversely, when there is less activity, and hence less blood is required, the tonicity is increased, and the vessels lessened in bore.

ABNORMAL TONICITY.—Thus there is an exceeding nicety of control of supplies all over the body, entirely without knowledge or attention, and it is only when there is some abnormal amount of activity, due to a spasmodic tonicity induced usually by some local cause, that pain draws our attention by the excitation of sensory nerve endings. Thus excessive intestinal contractions, due to the presence of some irritating cause, may give rise to severe intestinal pain, and the passage of a concretion,

FORMS OF ANIMAL CELLS

This plate illustrates the various forms taken by cells in the body of the higher animal according to the physiological work which they are called upon to perform.

No. 1, Shapes taken by amœboid cells. 2, Ovum or female germ cell. 3, Ciliated epithelium. 4, Flattened epithelium from mouth or nose. 5, Goblet-shaped single secreting shell for production of mucus. 6, Stratified epithelium. 7, Liver cells with bile passages. 8, Column of voluntary muscle. 9, Columns of cells of heart muscle. 10, Involuntary muscle fibre. 11, Cartilage cells. 12, Bone cells. 13, Secreting glands of stomach. 14, Absorbing projection or villus of intestine. 15, Kidney tubules. 16, Nerve cells. 17, Cells of retina of eye. 18, Taste cells. 19, Parts of a nerve-fibre. For fuller description see text.



FORMS OF ANIMAL CELLS

such as a gall stone or renal calculus, may give rise to the exquisite pain of biliary or renal colic. The sense of distress and difficulty of breathing in asthma are similarly due to an excessive spasmodic tonicity in the small respiratory passages. But, as stated above, all these are abnormal conditions, and the unceasing necessary nervous control which is carried out by the operation of the autonomous or sympathetic system on the involuntary muscular system, and is present every moment of our lives from birth to death, is entirely outside our knowledge as it is outside our direct control through the will.

OTHER FORMS OF CELL.—Returning to the forms of cell depicted in the illustrations, figs. 11 and 12 show those to be seen in the supporting tissues of the body, viz. the cartilages of the joints (fig. 11) and the bones (fig. 12), a separate bone cell being shown more highly magnified in the small figure. In the bone the cells are arranged concentrically around small openings which carry the blood-vessels, the concentric system being called a HAVERSIAN SYSTEM, after the name of the discoverer. It will be noted that the bones are really living structures containing living cells, and well supplied with blood-vessels. Their rigidity is secured by insoluble calcium phosphate secreted by and deposited between the cells, and their toughness by organic fibres, also secreted and deposited. In old persons the bones become brittle from excess of inorganic matter and defect of the organic constituents; conversely, in young growing persons there is much less inorganic matter and correspondingly more organic fibre, so that injury often does not completely snap the bone, so giving rise to the so-called green-stick fractures.

It may also be noted in passing that the bones, in addition to acting as supports, *are important gland structures*, for it is the *red marrow* found in the cavities in certain bones, such as the ribs and the heads of the long limb-bones, which rejuvenates the blood by keeping up the supply of red blood corpuscles as these become used up under normal conditions; and also after loss of blood by bleeding, or during recovery from anæmic conditions induced by disease, there is very rapid production of these important oxygen carriers in these situations in the bones. Hence the bones in this way form one of the most recuperative tissues in the body.

UNORGANIZED FERMENTS OR ENZYMES.—A section of a gland which secretes the gastric juice of the stomach is seen in fig. 13. The PEPSIN is secreted by the more numerous cells lying near the fine lumen or duct of the gland leading towards the stomach cavity at the upper end of the figure, while the hydrochloric acid is secreted by the less numerous darkly stained cells more removed from the lumen. The mixed secretion is poured out by the common duct of the gland, and such glands open side by side over the inner or mucous surface of the stomach. The pepsin in the presence of the acid digests the form of food known as PROTEIN, such as white of egg, the lean part of all forms of animal food, and certain constituents in milk (casein) and in bread (gluten), rendering them soluble and capable of absorption in the intestine. This pepsin is an example of the bodies known as ENZYMES OR UNORGANIZED FERMENTS. They are

all soluble products from living cells, and share many properties of living matter, such as that of being destroyed when heated above a certain temperature (50° to 75° C.), but differ in other respects, such as that of not being stopped in their activities to the same extent as are living cells by anæsthetics and antiseptics. Different members of this class of body induce by their presence the fermentative or digestive changes in the food, and also certain similar ferment processes in the body not connected with digestion, such, for example, as blood coagulation, and as oxidation changes in the tissues. They are not themselves chemically altered by the changes they induce, so that a small amount can produce a disproportionately large amount of chemical change, which is obviously a most economical and energy-saving arrangement in the body.

IMPORTANCE OF ENZYMES.—These enzymes have been most extensively studied in recent years. They are becoming of great industrial importance, and also of great value to the physician from their relationship to disease, for there is no doubt that many disease products are enzymic in their activity, and hence produce results out of all proportion to their amount. It has been shown that many bacteria contain what are termed intracellular enzymes, to which they owe their activity, and in certain cases, as, for example, the yeast organism, such enzymes have been obtained apart from the cell, and shown to be capable of causing enzymic or fermentative changes apart from the presence of the cell. The enzymes are also of interest to the biologist and bio-chemist, as a kind of halfway house between living and non-living matter, simpler in constitution and action, yet having many of the properties of the living cell from which they have originated impressed upon them.

ENZYMES AND CELLS.—No example of reproduction of an enzyme by means of the chemical change which it produces has yet been recorded, but instances of the genesis of similar inorganic substances in this fashion are known, and time and research may yet reveal such enzymes. All the other differences between enzymes and cells are of degree and not of kind. When we consider that in many cases the organisms producing disease are quite invisible and capable of passing through membranes which refuse passage to many forms of protein molecules (such as the Pasteur-Chamberland filter), so that it has become fashionable nowadays to speak of ultra-microscopic germs, it may be realized that the gap between cell and molecule is gradually being bridged, and that the cell visible under the microscope is ceasing to be the hard-and-fast arbitrary unit in biology which it was a generation ago.

The conception that the cell may hand on certain of its living properties to its products, and that cells, or bodies with cell properties, beyond the pale of microscopic vision, and approximating to colloidal molecules in their dimensions, may exist, appears to the writer to be one fraught with much interest for the future, and one which may play a great part in opening up to our knowledge the genesis or etiology of many of the commonest infectious diseases of temperate climates.

PROTECTIVE ACTION OF GASTRIC JUICE.—The hydrochloric acid secreted by the gastric juice (formed by the cells indicated in fig. 13)

is a natural germicide and disinfectant mixed with the food at a very early stage in the process of its digestion. Meat infected with micro-organisms, and showing the evident signs of commencing putrefaction, has been given to dogs, and it has been found that after about an hour in the stomach it has been disinfected and lost all signs of putrefaction through the destructive action of the hydrochloric acid on the organisms. It has further been shown that the strength of the hydrochloric acid (about 0.2 per cent) present under normal conditions in the stomach is quite sufficient to destroy all the common forms of pathogenic organisms. It is needless to point out the value of such a protective arrangement against infection, and under normal conditions of gastric activity that important entrance of foreign material to the system, the alimentary tract, is secure against infection.

A similar guard of unknown chemical nature exists between the small and large intestines, for while bacteria flourish in abundance in the large intestine there is a very sharp drop in numbers in the small intestine, much greater and more sudden than can be accounted for by the mechanical action of the imperfect valve between the two portions of the gut. As a result of this it is found in the normal animal that the contents of the small intestine are always sweet and free from infection, while those of the large intestine have the usual fæcal odour. There is thus a protective mechanism at both ends of the most important portion of the alimentary tract so far as absorption and uptake of infection are concerned.

The protective mechanism afforded by the acidity of the gastric juice has been shown by the writer to be peculiarly sensitive to changes in the general health, and any debilitating influence decreases the amount of acid and so increases the liability to infection by this channel. Thus a series of samples of gastric juice taken from hospital patients suffering from different causes gave an average of gastric acidity of less than one-third of that shown by a number of healthy persons, and in several cases the acidity was less than one-tenth of the normal. Such persons would be peculiarly liable to infection through the intestinal tract.

It is noteworthy that in cancer of any region of the body, and not merely in cancer of the stomach as was formerly supposed, there is a profound depression, in nearly all cases, of the gastric acidity, and this often in very early cases. This deficiency appears to be associated with an increased alkalinity of the blood.

VILLI.—The next figure (14) shows a longitudinal section of what is known as a VILLUS of the small intestine. The villi are small projections just visible to the unaided eye, which are closely set together like the piles of velvet, all over the absorbing surface of the small intestine, and give the inner surface, when the gut is cut open, a velvety appearance. It is a beautiful example of natural adaptation to function, how this simple contrivance so enormously increases the area for the absorption of the digested food.

Observe the small artery and vein in the more central part of the villus, connected by a branching network of thin-walled capillary vessels

for the uptake of the incoming nutrient matter, and also that between these vessels and the intestine there is a complete layer of prominent COLUMNAR CELLS. This layer is everywhere one cell deep, and possesses a well-marked striated border towards the intestine; at one point a goblet cell is shown similar to that previously described. These columnar cells possess most important functions, not only in the absorption of the food but in its assimilation in chemical form to the circulating medium of the body, viz. the fluid part of the blood (or plasma).

PANCREAS.—It has recently been shown that the columnar cells covering the villi furnish a chemical substance in the form of a secretion which has the office of stimulating the production of digestive secretion by the PANCREAS, the most important of the digestive glands, which yields the PANCREATIC JUICE, a digestive agent, as its name indicates, for all classes of foods. The pancreas has its situation in the upper part of the abdominal cavity, and surrounded by a curved loop of the intestine situated immediately after the stomach in the continuity of the alimentary canal. This loop is called the DUODENUM, because its length in man is about twelve finger-breadths, and the pancreatic secretion is poured in chiefly by one main duct, entering usually in common with the bile duct, or close to it, about 3 or 4 in. from the upper end of the duodenum.

INTERNAL SECRETIONS.—Returning to the columnar cells of the intestinal villus, we may point out that their most obvious function of absorbing the digested food is by no means their only service in the body, and that they follow what has been shown by many instances in recent years to be a rule in the body generally, that a tissue or set of cells, in addition to its obvious first-discovered function, carries on what might be termed secret service for the benefit of other classes of cells and for the economy as a whole, and this service is often as vital and indispensable as its more obvious office. This latter type of work is carried on by means of what are known as INTERNAL SECRETIONS of chemical substances with very distinctive and specific properties, which are thrown directly into the blood instead of being separated as an obvious secretion and segregated apart by means of a duct or number of ducts. It is for this reason that secreted substances thrown directly into the blood are termed "internal" secretions, an obvious secretion, such as the tears, the saliva, the bile, or the gastric or pancreatic juice, being termed an "external" secretion, or simply a secretion.

DUCTLESS GLANDS.—This process of internal secretion was first discovered in the case of certain glands in the body known as the DUCTLESS GLANDS or BLOOD GLANDS. These structures, absolutely indispensable to the life of the animal, although often minute in size, have no ducts (hence the name), simply because they have no "external" secretion, and their use for a long period was an insoluble riddle to physiologists. It is only in recent years that the discovery of internal secretions has shed a flood of light on this domain of physiology, and has not only elucidated to a great extent the functions of the ductless glands them-

selves, but has given an impetus which has led to many practical and far-reaching discoveries in connection with other glands and structures, and supplied knowledge and suggested lines of treatment in many hitherto obscure diseases. This chemical sympathy and service of correlation all over the body is one of the most prominent outstanding discoveries of our time, which marks an epoch in the progress of physiological science, and has brought us closer than any other discovery to knowledge both of the allied cell-life of the higher animal and of the inner working of each of those small microcosms, or chemical laboratories, which we call cells.

The subject will be considered more in detail later, especially in relation to recent work on the physiology of the ductless glands, and the elaboration and maintenance of the common nutrient fluid of the body, viz. the blood; but at present we have come across the first and a most perfect example in the columnar intestinal cell. This cell by its work contributes so largely to the manufacture of the nutrient medium that we may here finish a sketch of the more important of its functions.

PROTEOSES.—The columnar cell takes up the products of the digestive secretions upon the foodstuffs, but it by no means acts simply as a mechanical filter in this respect. The products obtained by the action of the digestive enzymes contained in the gastric and pancreatic juices upon the protein foods *are most virulent poisons* when introduced into the circulation directly. A few milligrams of these substances injected into a vein exercise a most profound depressant action first upon the whole vascular system, causing the blood-pressure to fall almost to zero, and secondly upon the tissue-cells in general, bringing about death in a few minutes. The effect is very similar to snake venom, which, indeed, resembles these substances in chemical nature, and like them is innocuous by the mouth. There is also a close chemical relationship here to many of the poisonous toxins of disease, which may in many instances be regarded as protein digestive products of the bacteria or protozoa introduced directly into the circulation. These poisonous chemical substanecs are chemically simpler than the ordinary tissue proteins of vegetable or animal origin taken in as food; they are collectively known as PROTEOSES, and are more soluble under many conditions than the native or tissue proteins; thus they are not coagulated on boiling their solutions, nor thrown out of solution by many chemical reagents which throw down the tissue proteins.

If the analogy of the building of an edifice be taken to illustrate the relationships, these proteoses may be regarded as rather gigantic building-stones, hewn by the action of the digestive enzymes from the tissue proteins of the food, and designed to be built up by the agency of the columnar cells first, and the tissue-cells later, into differently formed edifices (*i.e.* the cell structures and protoplasm of the tissues) of the living animal which has consumed the food. A great deal of the architectural construction and building up is commenced in the intestinal columnar cell, and the process is still further continued in the liver cells. For all the blood, with the new constituents taken up, is first

passed through the liver by means of the portal vein, which gathers up all the tributaries from its intestinal area before it is allowed to reach the heart and mix with the systemic blood passing by the main artery of the body (aorta) and its branches to the tissues in general.

That profound modifications occur at the first stage of all in absorption and assimilation, viz. in the columnar cell, is shown by the fact that the most careful chemical examination of blood from a mesenteric vein—that is, coming away directly from the intestinal wall—demonstrates not a trace of the poisonous proteoses of digestion, which have all become changed in the intestinal cells and built up again into the natural proteins of the circulating blood fluid, or plasma, of the living animal. These plasma proteins are very much alike in all the mammalia, in fact identical as far as direct means of chemical investigation are at present capable of showing us. They are divided into two classes of soluble proteids, called GLOBULINS and ALBUMINS, both of which undergo coagulation when heated, similar to the change shown by white of egg on boiling.

The chief basis for this classification, with which we are at present forced to be content, consists in minor differences in solubility in dilute and concentrated saline solutions. In all warm-blooded animals both globulin and albumin are present, and these bodies in all these animals are closely alike in chemical and physical properties; physiological testing of the blood fluid of one animal directly introduced into the circulation of another animal of not too closely allied a species, by transfusion into a vein, clearly demonstrates, however, that this apparent identity is illusory, and is due to our want of knowledge of the finer building up of the protein molecule of the blood fluid. For the plasma of one animal is a direct poison for the blood and the tissue-cells of another animal of a different species, and hence blood transfusion can only be carried out between two animals of the same or very closely allied species. In fact, the injected animal has, by the reaction of its cells, to protect itself against the poisonous plasma injected, just as if this were a poisonous toxin of disease, and if the amount of foreign plasma injected be too great, death is the rapid sequence. With a less amount than the lethal dose, the main result seen is a breaking up of the blood corpuscles of the injected animal, with a reddening of the blood fluid, termed "laking", the whole process being called CYTOLYSIS[1], or dissolving out of cells.

IMMUNITY.—With still more limited doses of the foreign plasma injected, no obvious results are seen in the animal treated, but a closer examination of the fluid separated from a small quantity of its blood shows that a most remarkable change has occurred. This experiment has led to a wide field of research on the manner in which the living cells reply to invasion by any foreign substance in the nutrient medium, not only rendering these substances innocuous at the time, but protecting for a longer or shorter period by providing supplies of material to fight fresh invasions; in other words, conferring what is known as *immunity*, an important subject in practical medicine, and one on which

[1] This special solution of the red blood cells is called *hæmo-cytolysis*, or, more briefly, *hæmolysis*.

injection experiments have recently thrown a good deal of light. The first results were obtained by injecting the blood serum (that is, the fluid part of the blood after coagulation has occurred) of one animal into another animal of a different species, *e.g.* the serum of the rabbit into the goat, or vice versa. The injections are made in small doses, on three or four occasions, at intervals of one or two days, and then a small quantity of the blood of the injected animal is taken and the serum obtained from it in order to demonstrate the new properties which it has acquired. If a little of this clear serum of the injected animal be taken and mixed with the clear serum of an animal of the same species as that used for obtaining the injection material, the remarkable result is obtained that the two sera give a precipitate of protein with each other.

This result is most significant, since it shows that the injected animal has now a new substance in its blood which possesses the property of precipitating the foreign serum to which it has been subjected. In other words, it possesses a protective agency in its blood against this foreign and poisonous material. Such bodies are known as PRECIPITINS, and are analogous to the agglutinins which we saw earlier were formed as a protection against micro-organisms in the body of an infected animal, and gave its serum the power of agglutinating these or assembling them in clumps (see p. 80). The number of foreign substances against which the living cells of the body are capable of preparing specific precipitins is legion, and to almost any protein substance or poison, animal or vegetable, a corresponding precipitin can be prepared by suitable injections. During the time that such precipitin exists in the body it is obvious that the animal has a greater or less immunity against further infection by that particular poison, and it is in this or a closely similar fashion that protection or immunity is conferred against certain infectious diseases by inoculation of attenuated viruses or attenuated cultures of disease organisms gradually increased in strength until many times the dose which would have rapidly killed at first can be borne with impunity as the resistance or immunity is increased. Some such mechanism as this is formed, for example, in vaccination against smallpox, in the Pasteur treatment of rabies in man, in the preparation of the ANTIVENIN used so successfully against snake bites in India, and in conferring immunity against glanders and anthrax in cattle, although the actual production of a precipitin *in the sera* may not be demonstrable. In certain animals there is a large degree of immunity, called here PASSIVE IMMUNITY, always present, so that such animals are protected against certain diseases, and this passive immunity not only varies from species to species, and with the particular disease, but from individual to individual in the same species, so that one individual is more or less susceptible than another.[1]

SERUM TREATMENT.—It is but a slight step forward to the vicarious

[1] It is at present a debated point whether the partial immunity and partially decreased virulence in cases of infection in communities which have been for some generations subject to a certain disease is directly transmitted or due to the gradual weeding out of the more susceptible strains of individuals by the disease. Probably both causes are contributory; at any rate it is certain that a form of disease breaking out for the first time in a community possesses many times the virulence it shows in subsequent epidemics.

use of the protective substances formed in the body of one animal by means of injections for the aid of another naturally diseased animal or person. The animal used for making the injections must possess a certain degree of natural immunity, so that it can withstand the injections, and yet enough of susceptibility to react to the injections and produce an active anti-body to them. This process is utilized for the production of protective or ANTI-SERA, which are obtained by inducing a high degree of active immunity in one animal by injections of bacteria, living or dead (*i.e.* vaccines), or the poisonous products from them (*i.e.* toxins) into the system of the aiding animal, and then drawing off the activated serum for the cure of the diseased animal or man in whose body the antiserum so obtained neutralizes a certain amount of the poisonous toxins of the disease. There is a clear distinction to be made here which gives an indication of the forms of disease in which we may hope to be able to produce curative sera, and of those in which the combat may be urged more advantageously along other lines. This distinction deserves some attention, since its neglect may lead to much useless labour in the attempt to produce curative sera.

The splendid success in obtaining a serum against diphtheria, which has so prominently reduced the death roll from that most dangerous infection, naturally led to the industrious searching out of similar sera for all other infectious diseases, which was crowned with success in a few cases, but gave insignificant or negative results in most others in spite of the manifold variations in forms of technique applied. These failures have not, however, been without their valuable rewards, and our knowledge has increased by the sidelight thrown into many obscure corners. Not only has the lesson again been taught that we must attack by different routes, and that there is no general panacea for disease, but we are now in a clearer position for defining those types of organism against which sera can be obtained from those where the serum treatment is not available, and where some other engine of medical warfare must be brought into play.

From the results obtained up to the present with serum treatment the general law may be drawn that it is only in the most virulent and rapidly fatal forms of infection, *where the toxin produced is one of high poisonous power and produced in small quantities*, that treatment by a curative serum is likely to prove efficacious.

Thus in diphtheria we have a most virulent toxin produced in small quantity at a very localized area of infection. The chemical substance produced is as virulent as snake venom, as shown by its lethal effects when given in very small doses to animals, by its rapidly fatal effects in patients in the natural course of the disease when its rate of production begins to outpace the natural ability of the body to manufacture the antidotes, and by the serious paralytic lesions which characterize its action and persist for a long time after strong attacks.

In the case of other infections, such, for example, as typhoid fever and tuberculosis, we have much larger quantities of much less virulent poisons (as shown by injection experiments, &c.) produced in much larger areas by an infinitely larger number of the parasitic organism.

Now, the effects produced by the antitoxins of the curative sera are very definitely in the nature of a fixed chemical reaction, in which, as in all chemical reactions, there is a definite fixed relationship in amount or weight between the two reacting bodies. So that a definite amount of antitoxin is required to neutralize a similarly definite amount of toxin. This is no theory, but an actual demonstrable experimental fact. The toxin and antitoxin in diphtheria can be obtained separately, and a fixed amount of antitoxin renders neutral a fixed amount of toxin, so that a mixture of the two in these proportions has no poisonous effect. It is upon this principle that the statement of the strength of anti-diphtheritic serum in so many units is based. Hence for the highly virulent toxin produced in small quantities only a small amount of antitoxin is required, while for the toxin of low virulence, but produced in large quantity, a correspondingly large quantity of antitoxin is required.

Accordingly we arrive quite logically at the apparent paradox that the more virulent the poison of a given disease the more amenable it is to treatment by a curative serum, which is in absolute accord with the results obtained. The animal used vicariously for the production of the antitoxin never reacts so as to give a great abundance of antitoxin in excess, the real weight or amount of uncombined antitoxin is never great in the serum, and hence it is only a most virulent poison producing its results on the tissues by small quantities which can be rendered inert in this way by a correspondingly small amount of antitoxin.

The case is different in the natural production of antitoxin in the body of the infected animal itself in chronic disease, for here there is none of the definiteness of the chemical reaction with fixed quantities. The cells of the body are all the time producing antitoxins to neutralize the toxins injected. Also the opsonins mentioned earlier, which aid the leucocytes in actually ingesting and digesting the diseased organisms, are always being produced in varying amount from day to day. Thus a protracted struggle goes on, the opsonic index being one day up and another down, and the amounts of antitoxins secreted also vary according to the fitness of the tissue-cells and leucocytes from day to day. This slow protracted warfare is quite a different picture from the short sharp fight with the diphtheria organism, where a comparatively small supply of antitoxin suddenly thrown in may determine the issue by taking off the excess of poison, and thus relieving the sharp pressure for antitoxin on the productive cells, so giving them just that short breathing space they require in order in future to keep the supply in advance of the demand and save the poisoning of the tissues. Then the leucocytes take the disease organisms in hand, the scale is just turned, and victory is soon with the leucocytes and tissue-cells.

But in the protracted struggle, say, of phthisis, the virus produced at first by the small area of infection which commences the disease is small in actual quantity, and also is low in its virulence per unit quantity, so that there is no general reaction of the tissues such as the more potent virus of the organism of diphtheria at once induces, the organisms are allowed to flourish, and the onset of the disease is in-

sidious and probably unobserved. As the disease advances, reaction becomes more general, and in actual amount both toxin and antitoxin are produced in much greater quantity, so that there is no point at which a small amount of antitoxin thrown in from without can turn the scale in the combat. The natural indications in such conditions are to keep the fighting tissues of the body as fit combatants as possible by attending to the general conditions, by good hygienic surroundings, by giving as much and as nutrient food as possible, and by throwing on no other strains of any kind, such as excessive work or fatigue. This is what the sanatorium and fresh-air treatment aim at, and the good effects obtained are due to the carefully regulated routine of the life, the regular and nutritious dietary, and the stimulating effects upon the lungs and tissues generally of the pure fresh air of equable temperature, promoting oxidation and avoiding those sudden variations in temperature of the surroundings which are so disastrous in all respiratory diseases. It cannot be too strongly pointed out here that what is required is pure fresh still air of even temperature, and not cold draughts through open windows.

RÉSUMÉ.—The discussion of the chemical work of the absorbing cell in providing the necessary chemical environment of the tissue cells from the more simplified constituents prepared from the food by the digestive enzymes has naturally led us to further discussion of the exquisite adaptation required in the nutrient fluid of the living cell. From that position we have gone on by easy transition to the reply of the cell, almost universal in its character, yet specific in each case, to abnormalities arising from foreign substances in that environment, so giving rise to agglutinins, precipitins, cytolysins, and antitoxins. Further, we have shown how medical science has attempted to utilize these natural specific replies to specific forms of stimulation or irritation in order to prepare remedies against disease.

HORMONES.—We may now return to the further work of the intestinal cell. Until only a few years ago it was believed that the whole work of secretion on the part of the digestive secreting glands was entirely controlled and regulated by the nervous system. That the sight of food, the tasting of food, and its mechanical contact with the walls of stomach and intestine reflexly set in operation through the nervous system the system of secreting glands, and led to the production and flow in ordered sequence of the whole set of digestive secretions. Thus the sensory nerves of vision or taste, or of the mucous membrane of the alimentary canal itself, sent nervous impulses up to a nerve centre in the medulla, and the stimulation so given to nerve-cells in the centre was transferred to so-called secretori-motor cells adjacent to them, and from these in turn reflex nerve impulses were sent down—along the secretori-motor nerve fibres—to the nerve endings surrounding the secreting cells of the digestive glands. It still remains certain that such systems of nerve-cells and fibres connected with the process of secretion exist and operate, and their relationship to the secreting structures and to the central nervous system, as well as the nerve channels through which they operate, have been carefully made out

by the work through many years of many patient observers, and none of this valuable labour has been lost through the new advances of recent days. It is a fact of common knowledge that the sight, taste, or smell of appetizing food makes the mouth water, or, in other words, causes the salivary glands to secrete their digestive secretion, and the work of Bernard and others in tracing out the nerve channels of this activity, as well as that of Beaumont, Pawlow, and others in showing that there is a similar reflex secretion of gastric juice, not so obvious to self-observation, preparatory for the arrival of the expected food in the stomach, remains as firmly based and as valuable as ever. There is no doubt that each important secreting structure in the body possesses a reflex nervous mechanism for controlling its activity, starting it into operation or stopping it. But in addition to this it has been shown more recently by Bayliss and Starling that there exists a chemical excitation for such secretions. These chemical excitants are known as HORMONES (Gr. *hormio*, I excite), and form a distinct class amongst the internal secretions.

The first to be discovered was the excitor of the pancreatic secretion, called SECRETIN[1], which was shown to be set free by the action of the acid pulp, coming from the stomach, upon the columnar cells of the duodenal mucous membrane.

It had been previously shown that injection of dilute acid into the duodenum had the effect of causing a copious flow of pancreatic juice from the pancreatic duct, but the action had been regarded as a reflex nervous one. As it was still found to occur after the main nerves running to the nerve centres in the brain had been severed, it was then supposed to be an example of what is called a local reflex, that is to say, a reflex, the nerve-cells of which lay peripherally close to the seat of action. In this case the seat of action was supposed to be in some of the nerve-cells of the sympathetic or autonomic system mentioned above as governing such nutritive physiological functions.

At this stage the matter was taken up by the discoverers of the first hormone, Bayliss and Starling. These observers found that even after severing all the minute nerve twigs situated around the blood-vessels passing away from intestine—so that a loop of intestine was freed from all nervous connection with the body but still had its blood supply—and now injecting dilute acid into the loop of intestine, a copious flow of pancreatic juice was obtained. In view of the known fact that certain other organs yielded internal secretions this at once suggested that the intestinal cells, when stimulated by the acid chyme arriving from the stomach, secreted and poured into the blood a chemical substance which passed into the circulation, and hence reached the pancreas. This substance, acting as a hormone, at once stimulated the pancreatic gland to produce the secretion required by the food in the intestine for its further digestion. Experimentation proved the accuracy of this view. The mucous membrane from a portion of the intestine was scraped off, extracted in a vessel with dilute hydrochloric acid, boiled, neutralized

[1] This word *secretin*, to designate a particular hormone, must not be confused with the very similar one *secretion*, which covers the whole class of internal and external secretions.

with alkali, and filtered; then this clear, filtered extract was injected in small quantity into a vein. In a few seconds there resulted a rapid flow of pancreatic juice.

A more perfect method of invoking a flow of secretion, just as it is wanted and in proportion to the requirements, than this of a chemical excitant or hormone is difficult to imagine. Further investigation has shown the existence of gastric hormones (Edkins) and of a hormone from the pituitary gland (*i.e.* a small structure attached to the under side of the brain) which excites the kidney secretion (Schäfer), and the whole subject is one of the hour, on which energetic research is being pushed in many quarters.

Nor is this the only internal secretion thrown out by the intestinal cell. Another equally important substance is cast forth in the opposite direction, namely into the intestine, and is called ENTEROKINASE (Pawlow). This substance has for its function the activation of the proteid ferment of the pancreatic juice after that secretion has reached the intestine.

The pancreatic juice possesses three ferments, TRYPSIN, AMYLOPSIN, and STEAPSIN, which act respectively on the three great classes of foodstuffs, viz. proteins, carbohydrates (sugars, starches, and certain gums), and fats. Now it is a remarkable fact that the pancreatic juice as it flows from the duct is entirely without action on proteins, and this whether it is called forth by nervous stimulation of the gland or by chemical stimulation. But, as shown first by Pawlow, if it be mixed with a little of the fluid from the intestine, or an extract of the intestinal cells, it at once becomes active. This action was shown to be due to a substance having many of the properties of the enzyme class, and, since its action is upon another ferment, it was fancifully called by its discoverer the "ferment of ferments". It is destroyed like other ferments by boiling its solutions, and a minute quantity of it can activate a large amount of pancreatic juice provided it be allowed a sufficient time, a larger amount of course completing the activation process in a shorter time.

It has already been pointed out that the hydrochloric acid of the gastric juice serves most important functions, and that its secretion is peculiarly liable to be upset. Attention may here be drawn to the profound effect of this upon the whole process of intestinal digestion. Even in the absence of hydrochloric acid there is usually a small amount of acidity due to organic acids, and this, in an imperfect and faulty way, is probably capable of stimulating feebly the intestinal mucous membrane to produce secretin, and this in turn pancreatic secretion, but the whole round of events must inevitably suffer if there is a scanty production of hydrochloric acid in the stomach.

To summarize the work of the intestinal cell: it takes up the products of digestion; from these products, which would be poisonous for the tissue-cells, it builds up the blood proteins, which are very specific for each class of animal. In addition, it secretes a substance into the blood which produces a flow of pancreatic juice, and another into the intestine which activates the pancreatic juice after it has reached the intestine.

NERVE-CELLS.—The remaining types of cell shown in the Plate, FORMS OF ANIMAL CELLS, are the secreting cells of the renal epithelium, shown

in longitudinal and cross section in fig. 15, and cells and fibres of the nervous system, shown in figs. 16 to 19 inclusive. Various forms of nerve-cell are shown in fig. 16, from the central nervous system and sympathetic nervous system, which are distinguished as unipolar, bipolar, and multipolar, according to the number of processes passing from them which set them in communication with one or nearly always more nerve-cells in their immediate vicinity or in more remote regions of the body. A thin filament from the cell passes into each of these processes, and gives it throughout its length physiological continuity with the cell. Also one or more of these processes is in continuity physiologically with some form of tissue, such as muscle, gland substance, &c., which is not nervous, and which is actuated or controlled by the nerve-cell. The end of such a process is called a nerve-ending, and various forms are taken on by these nerve-endings in different tissues to adapt them to their work. One of the processes from the nerve-cell is usually of considerable length and is known as the NERVE-FIBRE. This nerve-fibre is surrounded in many cases by accessory and protecting coats, in similar fashion to the insulating coats around a wire for conveying an electric current. Such a nerve-fibre is shown in fig. 19, which, from the thick middle coat, is called a *medullated* nerve-fibre. The essential part for conducting the impulses is the thin process in the centre, which is really a part of the nerve-cell, and may be some feet in length, to give communication between different parts of the body. In fig. 17 there is shown a portion of the retina to illustrate peripheral nerve-cells and their processes. These form a relay of nerve-cells between the nerve-cells in the brain and the endings in the retina which first receive and convert the light energy. The taste-cells from organs in the tongue which are first affected by the dissolved sapid substance are shown in fig. 18. The real taste-cells are the slender ones, seen at the right of the figure; the stouter cells, on the left, are cells which act as supports, and it may be as nutrient cells for these. Around the special gustatory cells the minute branched endings of the gustatory nerve-fibres break up in tree-like fashion, and the activity of the gustatory cells when they are stimulated causes, in some unknown way, impulses to pass up the gustatory nerves to a special set of central nerve-cells segregated off at a special region of the brain.

CHAPTER IV

BIO-CHEMISTRY

We may now turn our attention to the chemistry of the living cell, and to the chemical mechanisms by the operations of which the cell is enabled to carry out those peculiar chemical transformations of energy which give rise to the unique set of phenomena characteristic of life.

OLD VIEWS.—For a long time progress was barred in this domain of

physiology by the erroneous supposition that the chemical constitution of living matter, in its actual living condition, must be known definitely as a necessary substratum for work upon the chemical operations of the living machine. It was supposed that until we knew the actual chemical constitution of living matter we could not hope to acquire much knowledge of the nature of the chemical processes which went on in it during life. The student was carefully told at the outset of all treatises on physiological chemistry that the matter of living cells was killed at the outset by the very reagents used to examine into its nature, and hence that all our knowledge referred to dead matter, to matter which was once living but alive no longer. It was then usually added that we could examine what went into the living machine and what came out of it, we saw the beginning and the end of the process, and could chemically examine the initial and the end products of the cell's work, but the intermediate products and processes were very obscure to us, and must remain so until, first, the chemical nature of proteins had been demonstrated by processes of analysis and synthesis, and later, the mode of union of these to form the constituents of the living machine.

NEW VIEWS.—It is only recently that bio-chemistry, stimulated by the advance in physical chemistry, and especially by the work done in that subject on the conditions varying chemical reaction and governing and controlling the velocity of reaction, has begun to escape from the weight of this interdict, and commenced in real earnest to study the march of events in the living cell and the effect of variations in the conditions of life upon the activity of the cell and its derived products. Many of the brilliant results already described above have flowed from such study, and in bio-chemistry at the present time important results are constantly being obtained by the actual study of the living cell under experimentally varied conditions, rather than the study of the organic chemistry of dead cell products and destroyed living matter. Indeed so little necessary is an exact knowledge of the organic chemistry composition of the cell as a preliminary to cell study, that it may be confidently predicted that the old conception will be exactly reversed, and that the study of the cell's activity, without previous knowledge of the exact chemical constitution, will ultimately lead us to a knowledge of the essential constitution of living matter, and it may be pointed out that it is by similar lines of investigation in chemistry and physics that we have reached our present knowledge of other transformations of energy in these subjects. The view of the chemical constitution of living matter set out below, which fits and correlates the known facts regarding the chemical changes and energy display of living matter, has been arrived at by an inductive process from the observed energy transformations of living matter, in an exactly similar way to that in which theories as to magnetic and electrical fields, and as to light and radiant energy propagations, have been arrived at by physicists, from a study of experimental observations.

The conception that we must first thoroughly understand the chemical build of living matter before we can begin satisfactorily to study the

living cell and its chemical transformations is as futile as would be a suggestion that we could not study magnetic energy until we knew what was the intrinsic peculiarity in iron which caused it to be capable of magnetization. To take a still closer example, even in inorganic chemistry and in the simplest types of reaction we know no more than we do in the living body of what is the intermediate state of the reacting constituents in any given reaction. In both cases what we really do know and can examine are the initial and the end products, and the results in certain cases of abnormally interrupting the reaction at certain stages. But, in these latter cases, it must be clearly pointed out, that by the very act of interruption we convert these so-called intermediate products into end products, and even admitting that they are temporarily formed in the normal reaction, this does not teach us how they are formed. The passage from one form to another is what is hidden from us, both in the simpler reactions of inorganic chemistry and in the more complex chemical reactions presided over by the living cell. We possess no real knowledge of the cause of what is known as chemical affinity, and very little of its variations in the act of a reaction when the reacting constituents are first produced and most active. But we do know that chemical affinity exists, that there is a nascent state, that, as a result, chemical reactions occur under conditions which we can study, and that we can investigate the energy changes that occur in the reactions, including the changes in matter as a result of the reaction. This is the work of inorganic chemistry, and the confines of study are no straiter for the bio-chemist in the study of the chemical life-history of the cell.

THE CELL AS ENERGY TRANSFORMER.—The starting-point is essentially the same in all branches of exact study in physics, chemistry, or physiology. In all cases we have matter in some peculiar form which constitutes it a machine for transforming energy along some path or other, giving its special manifestations by the way. Energy is fed into the machine in some form or other, and evolved in other forms. In quite recent times many new forms of manifestation of energy have been discovered in the domain of physics and chemistry, due in each case to a peculiar form of energy converter or transformer, such, for example, as the X-rays or Röntgen rays, and the radium rays and emanations. It seems singular, therefore, that with a special type of energy transformer, such as the living cell, there should be any difficulty in conceding a special type of energy set free by this transformer. The explanation really is that in the past there existed a mischievous conception of a mystic vital force totally distinct from all other forms of energy. The reaction from this ought not to lead us to the other extreme of denying the existence of a peculiar set of energy phenomena in living matter, which indeed characterize it and show it to be living.

The criterion in physics and chemistry that we have before us free energy in a distinct form, such as X-rays, radio-activity, magnetic energy, light energy, heat energy, electrical energy, or mechanical energy, is that there exists a set of experimental phenomena peculiar to the given form of energy, and which cannot be reduced to the operation, in the

same identical way, of another form of free energy. The distinct characteristics of each of the free forms of energy mentioned are too obvious and well known to require statement, but each form can be made to pass into one or more of the other forms by the action of suitable transformers, and in so doing obeys the well-known law of conservation of energy.

Now, when the chemical energy of the food passes into the living cell (a peculiar energy transformer different from other transformers), and is there set free, it gives rise to a characteristic set of energy phenomena, intrinsic for living matter, which cannot be imitated except by living matter, and this is exactly the criterion stated above for distinguishing different free forms of energy from one another. The set of phenomena observed when chemical energy is converted and set free by the living cell are as distinct from any of the forms mentioned above as these are from one another, and although chemical and electrical energy and heat are simultaneously set free, and the peculiar energy of the living cell passes ultimately into these forms, intermediately a train of phenomena is fired off distinctive in character for the living cell, and not found elsewhere. This concomitant setting free of other forms is seen in all other energy transformations. Thus, for example, X-ray energy gives rise to chemical change in a photographic plate, or passing into opaque objects it is converted into heat, or on reaching a phosphorescent screen it gives rise to light energy, but in its passage to those well-known forms it gives rise to its own peculiar set of phenomena. It is hence in the passage or transformation that the characteristic properties of a form of energy become known, and it is no objection to the form of energy being distinct that it gives rise to well-known forms on the way. It is distinguished by the manner in which it gives rise to those well-known forms. All experiments in physics, chemistry, and biology are fundamentally a study of such energy transformations.

BIOTIC ENERGY.—The form of energy set free by the cell, and the set of energy phenomena characterized by it, may be spoken of as BIOTIC (Gr. *bios*, life) energy, to prevent confusion with the older terms of vital energy and vital force, which were used with quite a different signification. The cell, on account of its peculiar physical and chemical structure, acts as a transformer for converting chemical energy into biotic energy, as a dynamo acts for converting mechanical energy into electrical energy. Once obtained, this biotic energy may be utilized for chemical synthesis or other purposes, just as the electrical energy obtained from a dynamo may be used to obtain chemical energy for electrolytical processes or for other chemical syntheses.

The peculiar energy changes seen on the way in the case of biotic energy are such as irritability and contractility of the living matter, production and propagation of nerve impulses, alterations in the structure and arrangement of cells, cell-division and the reproductive processes, periodic variations in activity, secretion and synthesis of chemical substances. In fact, a more characteristic and unique set of phenomena to differentiate a form of free energy cannot well be imagined or demonstrated elsewhere amongst the many energy changes known to us.

THE EQUILIBRIUM OF THE CELL.—When we come to examine the operations of the living cell as a peculiar energy transformer, in the manner above indicated, by studying the variations produced by altering its conditions of life, food supply, &c., or by stimulating it with foreign substances, we find that the living matter of the cell is in a state of very delicately balanced chemical equilibrium, which has been described as a *labile* equilibrium. There is a continual flux of energy through it, but in its normal state it is itself in equilibrium, continually transforming the energy of the food, and so obtaining energy for its work, but itself only slowly changing and undergoing modification.

The essential fundamental thing about the living cell, in all its varied forms and varied activities, is that it itself is in a condition of continued stability under given conditions, while its parts are unstable and all the time undergoing change. The chemical matter of which it is composed, is known experimentally to be endowed with great chemical receptivity for a very large and varied number of other chemical substances, and this chemical receptivity is such that the substances are very lightly held and as lightly let go again.

If the attachments by weak chemical bonds are made too strong by any process, as by too high a pressure or concentration of a given substance in the cell, the result is as fatal to the cell as if the pressure or concentration of a necessary substance were reduced too low and the cell were starved of it. The constitution becomes fixed, and the cell loses that property of seizing and releasing which is the fundamental necessity of its existence.

The whole strength of the cell lies then in the weakness of these chemical bonds or links formed between its substance and the molecules of food, &c., from its environment. The nutrient substances must be present in sufficient concentration in the cell fluid to form these weak chemical associations or combinations with the cell substance or protoplasm, they must not be in such concentration as to give too strong a tendency to association, or the handling of the nutrient material, so to speak, by the cell will be interfered with, and the cell will lose its power of rapid association and dissociation, accompanied by chemical transformation in the process.

It may also be pointed out that the food substances must have a similar unstable composition to the cell substance itself, otherwise the task of breaking up and rearranging by the cell will be beyond the power of the energy it has at command, and this condition is satisfied by the proteins, carbohydrates, and fats of the food. In the green plant, where these unstable organic foodstuffs are built up, the energy of the sunlight is available, and this condition does not hold.

Hence in the cell, in order to establish the condition of mobile or labile equilibrium, there must exist a very light chemical attachment, and equilibrium of this order is only possible between certain well-marked and definite limits, outside of which life is equally destroyed by excess or deficiency of a given substance.

PROTEINS OF THE CELL.—If we glance for a moment at the chemical

basis for this fluctuating equilibrium which characterizes the living cell, we find it in the peculiar constitution of the protein molecules from which the protoplasm or bioplasm of the cell is built up. This living material is built up by the union in delicately balanced equilibrium, partially physical and partially chemical in character, of several slightly different protein molecules. Each of these protein molecules in turn is built up by the union of a number of what are known as AMIDO-COMPOUNDS, and it is on the chemical constitution of the amido-compound that the similar property of the living matter for feeble, easily disrupted and rearranged combination and dissociation in turn ultimately depends.

As a type of these amido-compounds we may consider the *amido-acid.* This is essentially an organic acid, such, say, as acetic acid, which has reacted in such a way with ammonia that one of its hydrogen atoms has been replaced by what is termed the *amidogen group*—that is, ammonia less one atom of hydrogen, giving rise to a monovalent radical ($N\,H_2$). As a result of this combination the amido-acid formed acquires what might be described as a kind of chemical polarity, for its original organic-acid group, known as the *carboxyl group* ($COOH$), persists, and from the presence of this it can still act as an acid, though more feebly than before, and it has at the same time, by the entry of the amidogen group, acquired basic properties in a feeble degree, so that it has now the power to combine with acids and neutralize them. The fundamental property of the amido-compound, then, is that it can at the same time act as base or acid, and combine feebly with acid or base respectively in this capacity. Since the vast majority of organic substances possess the properties of feeble acids or bases, this property admits of a wide field of very feeble chemical combination. A good example of such combination in the body is that by which the bile acids, which perform such service in the body in the taking up of the fatty acids formed in the digestion of the fats of the food, are formed by the combination of two amido-acids called *glycocoll* and *taurine* with cholic acid to form the *glycocholic* and *taurocholic acid* of the bile.

Most important results towards the chemical synthesis of proteins have recently been obtained by E. Fischer, who has produced artificially long strings of union between such amido-compounds, yielding bodies of high molecular weight which he has termed POLYPEPTIDES. These polypeptides show many, though not all, the reactions of protein bodies formed by natural synthesis in the living cells of the body.

To those unacquainted with chemical formulæ the method of production of polypeptides and of the body proteins from amido-bodies may be well illustrated by comparing the simple amido-body to a magnet of which the amidogen group represents one pole, say the north pole, and the carboxyl or organic acid radicle the opposite pole, say the south pole. We may then imagine that each constituent amido-compound has a different chemical constitution as regards its own internal molecular arrangements, provided it has these two groups giving it the required polarity, or, in chemical language, at the same time acid and basic properties. If now a number of such amido-compounds are brought

close together in the chemical sense and under suitable conditions, they will combine together, amidogen to carboxyl, just as a number of simple magnets would attach themselves north pole to south pole, and there is no limit to the number of such amido-compounds so uniting to form a giant molecule, except that the instability of the mass will increase with its size.

Importance of Instability.—This very instability is the cardinal virtue in the living bioplasm, because it admits of continued rearrangement of form with consequent ability for taking up and casting off constituents and for disrupting these along certain lines of cleavage.

In order to make the magnetic analogy complete we have only to replace the idea of magnetic polarity by that of a chemical multipolarity, so as to allow our growing bioplasmic molecule to spread out in all directions of space. For with a bipolarity we could always only have two free poles of opposite kind, and it would only be possible to have long linear strings of molecules. But the nature of chemical molecular constitution and the spatial disposition of constituent groups postulated by modern stereo-chemistry gives us just the necessary freedom in this respect.

Experimentally, also, amido-compounds are known which possess around one central chemical nucleus more than one acid (carboxyl) and more than one basic (amidogen) group. So that at any stage in its process of growth the developing protein or bioplasmic molecule will necessarily possess a number of outstanding basic and acid affinities ready for the attachment of fresh members to the growth. A stop to any of these free attachments can be made by its becoming united to a kind of unipolar member, such as a kation or anion of an inorganic salt in solution,[1] or to an organic element of similar properties, such, for example, as a feebly basic molecule of glucose or a similar carbohydrate, or to a molecule of a free fatty acid such as oleic acid.

Final Conception of Living Molecules.—Putting the matter in language as free from technicalities as possible, the final conception at which we arrive for our bioplasmic molecule is that of a very large chemical structure built up of a number of smaller constituent chemical structures each having polarities of two distinct kinds, which bind the smaller structures together, and of these chemical polarities a number are left free or but feebly united to each other, which can attach other matter coming in from the environment to the bioplasmic molecule. The strength with which any constituent will become attached to, and remain in union with, the bioplasmic molecule will depend on many factors, but two of the most important of these are, first, the natural chemical structure of the given bioplasmic molecule and of the given constituent, and, secondly, the concentration of the constituent in the

[1] The modern theory of ionization in solution (see Vol. II, p. 77) states that when a saline substance passes into solution a varying number of its molecules detach into *ions*. Thus common salt (NaCl) forms sodium ions $\overset{+}{\mathrm{Na}}$ and chlorine ions $\overset{-}{\mathrm{Cl}}$; of these the $\overset{+}{\mathrm{Na}}$ ions are capable of forming molecular attachment with the organic acid or carboxyl groups, and similarly the $\overset{-}{\mathrm{Cl}}$ ions with the amidogen or basic groups.

cell fluids. The more concentrated the constituent the greater will be the number of molecules of it united to the bioplasm at any given instant, and if its concentration diminishes, then there will be a corresponding decrease in the number of molecules attached, and the greater number of attachments will the bioplasm have for other chemical activities. Hence, between certain very definitely fixed limits for each constituent in the cell's environment, there will be what might be described as a range of association and dissociation.

If the constituent be an essential one for the life of the cell, so that indispensable reactions cannot go on without it, such, for example, as oxygen, then below a certain limit of concentration there will be so little attached in the cell that the life processes cannot go on by reason of shortness of supply. If, on the other hand, the concentration of the essential constituent surpass a certain maximum limit, the pressure produced is so great that the constituent becomes firmly fixed in the cell in a definite position from which it cannot be dislodged, and the cell equally perishes from very plethora of the substance.

MEDICAL ASPECT.—This cessation of the activities of the living cell from excess of a substance in its environment is one which is of deep underlying importance in most of the modern practical problems of experimental medicine, and its influence has not been appreciated with sufficient force. For example, it lies at the very root of the activity of anæsthetics and the rational regulation of that activity, the action of toxin and antitoxin on the cell, the proper dosage of drugs and curative agents, the activity of enzymes upon their substratum and limitation of their activity by accumulation of products of digestion, and the adequate removal of waste products.

As an example we may take the carriage of oxygen, for oxidation purposes, to the tissues and the removal of the waste product, carbon dioxide, from the tissues. The red blood corpuscles in the blood coming from the tissues to be aerated in the lungs have a low concentration in oxygen, and the higher concentration of the oxygen in the fluid lining the lung surfaces, conferred by contact with the air in the lungs, causes a diffusion of oxygen into the corpuscles, where at that higher concentration it forms a loose compound of the type we have been describing; but when the blood reaches once again the tissues where oxygen is always being used up, it comes to a zone of low pressure, and the loose compound dissociates, yielding oxygen for diffusion to the active tissues. It is easy to follow the effects of a diminution or failure of oxygen supply in the lungs. The loose compound is not formed in sufficient quantity to supply the wants of the cells, and, after a brief period of excitement and chemical disruption, there follows death of the animal. Let us turn to the effects of excess of oxygen, such as are produced by breathing pure oxygen at two atmospheres of pressure, that is, at about ten times the normal concentration in the atmosphere. The result of this is in a short time a tenfold pressure in the fluid bathing the living cells, which as a result become saturated with oxygen, and this, instead of facilitating oxidation processes, causes the oxygen to become definitely and immovably fixed in one posi-

tion, and the cell perishes from want of power to manipulate the oxygen supply for its needs. The result is death, with symptoms exactly simulating those of asphyxia from lack of oxygen.

Equally instructive are the results arising from excess of carbon dioxide in the respired air. Under normal conditions the venous blood, returning from the tissues with a higher pressure of dissolved carbon dioxide, gives up that gaseous product of oxidation in the tissues to the air in the lungs, and on its next return to the tissues the blood is in a condition of reduced pressure in carbon dioxide, which enables it once more to take up a fresh supply of the excreted waste product from the cells of the tissues.

But when there is an accumulation of carbon dioxide in the lungs, diffusion from the blood cannot occur until the pressure in the venous blood rises above that in the lungs; as a result, the pressure of carbon dioxide rises all round the circuit and in the tissue-cells. The bioplasm of the cell becomes charged with carbon dioxide, which behaves like an anæsthetizing agent, stilling, after an initial period of excitement, the activities of the cell and suppressing the chemical activities there by the more stable union due to the higher pressure. The observed results are drowsiness, followed, if the pressure goes on, by unconsciousness, coma, and eventually death, just as occurs with too heavy a dose of an anæsthetic.

In addition, the carbon dioxide displaces, as its pressure increases, other less stably held constituents, such as the carbohydrates, which the cell always contains, giving the interesting result of a kind of diabetic condition shown by the appearance of sugar in the urine. A similar temporary appearance of sugar in the urine is seen in prolonged and heavy anæsthesia caused by an anæsthetic such as chloroform or ether.

ANÆSTHETICS.—It has recently been shown that the wonderful effects of anæsthetics in producing unconsciousness and inability to feel pain are due to a similar combination between the bioplasm and the anæsthetic. When an anæsthetic such as chloroform is administered, this passes from the air of the lungs into solution and reaches the blood, by which it is carried to the tissue-cells. The first tissue-cells affected are those of the central nervous system, causing loss of consciousness; but with sufficient strength of anæsthetic other cells follow, for even a bacterial cell can be anæsthetized with a sufficient strength of the anæsthetic.

The safe dose is that which just affects the higher nerve-cells, leaving the nerve-cells which control the act of respiration and those of the heart muscle unaffected. As the anæsthetic attaches itself to the nerve-cells, their chemical reactions, on account of this counter attachment, become stilled in greater or less degree in their activities according to the concentration of the anæsthetic in the circulating blood, which in turn varies with the strength of the chloroform vapour administered in the air taken into the lungs. When the air breathed contains about $1\frac{1}{2}$ per cent, the anæsthesia is still insufficient to prevent pain being felt in surgical operations; at about 2 per cent surgical anæsthesia is complete, and the patient feels no pain; at about 3 per cent the respiratory centre and other lower nerve centres are rapidly affected, breathing stops, and death soon results Hence the safe amount lies at about 2 per cent.

It is here seen how the depth of anæsthesia advances *pari passu* with the degree to which the bioplasm enters into chemical combination with the chloroform, and continues as long as that combination is maintained by an adequate pressure or concentration of the anæsthetic in the blood. As soon as the operation is over and the administration of the anæsthetic is stopped, the anæsthetic diffuses off at the lungs, the concentration in the blood is lowered, and the temporary compound between bioplasm and anæsthetic dissociates so that the bioplasm is enabled to renew its normal chemical activities, and consciousness returns again.

HYPNOTICS.—The action of drugs given as hypnotics for inducing sleep is a similar one, differing only in degree from that of anæsthesia. So also is the coma, or drowsiness and stupor passing into unconsciousness, seen in certain forms of kidney disease, where unremoved products of protein waste combine with the bioplasm and still its activity for normal chemical reactions; and in diabetes, where acid products formed in an abnormal manner similarly accumulate, and by chemical combination limit cell activity. The excitation of alcohol drinking, followed by stupor when taken in greater excess, is another example of such partial anæsthetization by chemical combination.

POISONS.—The action of all poisons taken into the system from without, or of the toxins formed by disease organisms, is again due to more or less stable combinations between such substances and the living material of the cell.

FATIGUE AND NORMAL SLEEP.—It is the accumulation of normal waste products in the blood which gives rise to fatigue; and this fatigue, as the effete products increase, leads up to drowsiness and the desire to sleep, in which condition, on account of the lessened activity of so many tissues, the excretory organs work at a greater rate in elimination than there is production of fresh waste products. Accordingly the concentration of waste products in the nerve-cells, which are the first cells affected in fatigue, decreases, the combination between waste products and the bioplasm of the nerve-cell dissociates off, similarly to that combination between anæsthetic and nerve-cell substance already described, with the result that the nerve-cells again become active. Waking occurs, from the incidence of some slight stimulus, as naturally as did the falling off to sleep when the nerve-cell substance was hampered in its chemical interchanges and rendered dormant by that accumulation of waste products which have now been worked off in the hours of sleep.

DIFFERENCES BETWEEN CELLS.—That very complex building up which confers this peculiar balanced labile equilibrium, common to all living cells, gives by variations in the building constituents room for a certain degree of specific difference between one cell and another. This specificity is seen not only in the nature of the different substances formed for different useful purposes in the body by the different classes of cells, but in a variation in the action of substances in the environment upon different cells, so that one substance or one drug affects chiefly one set of cells, and a second substance affects a quite different set of cells.

SPECIFIC ACTION OF DRUGS.—In this way arise the specific effects

of different drugs upon different parts of the body, the attack, often most specific, of different poisons and disease toxins upon special types of cells, and the definite localization of the lesions of disease. Just as an anæsthetic first attacks the higher nerve-centres, and only when it is pushed in amount encroaches upon others, so there is a similar specific picking out by poisons, and a spreading afterwards to other tissues in lessened degree. This selective capacity, according to the finer upbuilding of the bioplasm of the particular cell and the adaptation to that build of the substance stimulating, is the fundamental factor in the chemical sympathy between different organs and cells of the body, which was alluded to earlier, and is one of the most important facts to grasp in the whole of bio-chemistry. The same selective action is always observable in the case of the enzymes secreted by the cells, which only act on suitable substrata with a very definite chemical conformation, and indeed the enzymes themselves are in each case unique products of the cells producing them, cannot be simulated otherwise, and are only found in nature as products of such secretion by such definite cells.

Even the combinations of this unstable, easily dissociated character between the cell substance and the inorganic constituents of its environment are indispensable to the life of the cell, and if they are removed or are present in abnormal quantity outside certain well-marked limits the cell ceases to functionate and its life is destroyed.

Inorganic Salts and the Heart.—This has been shown with exquisite refinement in the case of the beat of the heart. The heart of an animal can be removed after death, even in the case of the mammal, and kept beating in a normal rhythmic way for hours, provided certain inorganic salts are present in a circulating fluid which is passed through its vessels. Strange to say, it is not in the first degree organic nutrients, such as proteins, carbohydrates, or fats which are required for this purpose, although ultimately in time the heart requires such organic nutriment like any other living tissue. But for hours it can live on its stored-up nutrient matter, while a few minutes are sufficient to determine its death if it be shut off from its due supply of inorganic constituents. If only distilled water containing a normal amount of sodium chloride, together with traces of potassium chloride and calcium phosphate, be supplied to it, it will beat with normal force and rhythm, as if it were in the body and supplied with blood, for hour after hour. The balance between these inorganic constituents is, moreover, a most delicate one. If a solution of sodium chloride alone, containing 9 parts in 1000 of the salt, be perfused through the blood-vessels of the heart, then after a few beats the heart becomes irregular in its rhythm, and soon the beats cease entirely. If now this fluid be changed quickly for one containing the same amount of sodium chloride, but in addition to this salt so little as 1 part in 10,000 of potassium chloride, and a still less quantity, amounting to a mere trace, of calcium phosphate, then the heart recommences beating and goes on quite readily. Further, if the amount of potassium chloride be doubled, from this small amount the heart again becomes irregular in a different fashion to that seen before with the sodium chloride solution

above, and in a short time again stops beating. All three constituents are requisite, and requisite in definite proportion, to form a proper, circulating medium. The case is once again that of a certain range of pressure, just that which is sufficient to give the proper association and dissociation balance, and appreciable deviation in either direction is fatal.

INORGANIC ELEMENTS IN FOOD.—This example of the beating heart has been given at some length, not merely because it furnishes such a beautiful example, but because what is true for the heart, where the beat gives such a manifest outward visible sign of activity, is true for every cell and tissue in the body, and has in many instances been demonstrated by experiment. The inorganic constituents taken in with our food, although not oxidized, and not therefore yielding any supply of energy for doing work in the body, are as indispensable factors for the normal working of the body as the actual organic foodstuffs. Not only is this the case under normal conditions: the qualitative and quantitative character of these salts vary in different foods, the foods of animal origin and the dry cereals, for example, being rich in phosphoric acids and yielding an acid ash, while the green vegetables and fruits are rich in alkalis, and particularly in potassium salts. As a result, feeding exclusively or excessively on certain particular types of foods is a prominent causative factor in producing certain important forms of disease, especially where there exists in the individual an idiosyncrasy, or sensitiveness, or, as it is called, a *diathesis*, in certain directions, leading to accumulation and heaping up of a wrong distribution of the inorganic salts. Amongst diseases in which this is observable may be mentioned scurvy, gout, and rheumatism. Just in the same way that the heart in the above experiment became loaded up and inactivated by a wrong distribution of inorganic salts in the perfusion fluid, so in these diseased conditions the tissues become loaded up with effete products from a pathological distribution of saline constituents.

This subject is one deserving of more investigation than it has hitherto received, but recent work tends to show that the inorganic constituents of the dietary require as careful consideration as the organic constituents which have hitherto received the almost undivided attention of the physician.

THERAPEUTIC EFFECTS OF INORGANIC SALTS.—The profound effects of the small variations in inorganic constituents, above described, on the isolated heart also throw a great light upon the great effects obtained in therapeutics with very small amounts of drugs of inorganic nature proportionately to the body weight—on the effects, for example, of small amounts of bromides or iodides, of mercury or iron salts.

Another perplexing question of therapeutics has also been elucidated by our recent progress in physical chemistry, namely that, within certain limits, all different salts of the same metal or the same acid have the same specific therapeutic activity. Or, in other words, that the action is that of the base, plus that of the acid present in the salt, and not that of the salt and varying with the salt. For example, amongst bases, all potassium salts, all mercury salts, all iron salts have the respective actions of potassium, mercury, and iron, more or less irrespective of the acid

with which they are combined; and amongst active acids all nitrites, all bromides, and all arsenates have their respective activities apart from the base with which they are combined. This is an important general law to which the modern chemistry of solutions furnishes the key. The laws of electrolysis in solution, backed by certain physical abnormalities of saline solution[1] show that in such saline solutions what is termed ionization occurs; that is to say, each molecule of dissolved salt splits up into two parts, which are called ions, and which confer the property of electrolytically conducting the electric current. For example, sodium chloride ionizes (or dissociates) into sodium ions ($\overset{+}{Na}$) and chlorine ions ($\overset{-}{Cl}$), and potassium bromide into potassium ions ($\overset{+}{K}$) and bromide ions ($\overset{-}{Br}$), and so on. These ions are not the same as sodium, potassium, chlorine, bromine, &c., as we know these elements in bulk, but are a form of matter found only in such ionized solutions. The plus or minus sign over the symbol of the ion indicates the opposite pole to that to which the given ion moves in the electric field when the solution is conducting an electric current, and the theory of electrolytic dissociation postulates that each ion carries an electric charge, and this confers on it its peculiar ionized condition.

Thus we see that the therapeutic properties in such ionized solutions depend upon the ions present in the solution, and not upon the salt molecules as present in the solid substance. It follows that in cases where the activity of one of the ions only is required, this must be prescribed with an inert ion, which occurs in the body fluids in considerable quantities. Now, the most abundantly occurring salt in the body is common salt, or sodium chloride. Hence, if the action of a metallic ion alone is required, it is given as a chloride; and if the action of any acid ion is required, isolated from other effects, it is given as a sodium salt. To take a specific example: if the combined actions of the potassium ion and iodine ion are required, they may be obtained by giving potassium iodide; if the potassium ion alone is required, it may be obtained by administering potassium chloride; and that of the iodine ion alone, by prescribing sodium iodide.

The ionic theory also furnishes an explanation of the very varying action of the same element in different combinations, for in these combinations the ion present in the solution is quite different, although the same element is present in both cases. Thus the ordinary salts of phosphoric acid (the ortho salts) are comparatively inert, and are present in normal conditions in all the body cells. But if certain of these inert ortho-phosphates are heated, the salts known as the meta- and pyro-phosphates are formed. These ionize differently in solution, and the solutions are very active and highly poisonous. Again, arsenic acid is much less poisonous than arsenious acid, and the organic salts containing arsenic are still less poisonous, because again they contain a

[1] These abnormalities need not be followed at length here. They are variations in freezing-point, boiling-point, and electrical conductivity of these solutions, which show that there is an abnormally high osmotic pressure in such solutions, due to separation of the constituents of the dissolved salts, as stated in the text.

different ion. Thus the drug known as ATOXYL, which has recently been employed in the treatment of sleeping sickness with great success (see p. 146), has less than one-twentieth of the poisonous action of arsenious acid.

CHAPTER V

ORGANO-THERAPY

We may now pass to the consideration of what might be termed the internal therapeutics of the body itself, for a number of therapeutic agents of great value are naturally formed in the body by the activity of its own cells, and some of the most valuable drugs of modern therapeutics have been discovered by the physiological study of the action of the different organs, giving rise to the branch of science now known as organo-therapy. In some instances these natural drugs are prepared from the organs secreting them, in order to furnish an adequate supply in individuals where the natural secretion is deficient; in other cases they are isolated and used in experimental operations to simulate the office they naturally carry out in the body. An example of the former is seen in the application of thyroid preparations in the disease called myxœdema and in congenital defects of the thyroid gland, and an example of the second is seen in the present extensive employment of the active material of the suprarenal gland in obviating bleeding or stopping bleeding during or after surgical operations.

THE SUPRARENAL GLANDS.—The suprarenal glands are two small glandular structures, so called from their position just above the kidneys. These two small glands in man do not exceed an ounce in weight, yet they are absolutely indispensable to life. Occasionally their activity is destroyed slowly during life, most frequently by their invasion by tubercular disease. When this occurs, an exceedingly well-characterized malady, known as ADDISON'S DISEASE, after the name of its discoverer, makes its appearance. One of the peculiar results of this diseased condition is a very marked bronzing which develops in certain parts of the body, and is most characteristic. At the same time the patient suffers from profound lassitude, which chiefly affects the muscular system, and soon the slightest exertion tires him. The appetite fails, the patient can scarcely eat at all, and there is great wasting, and frequent attacks of dizziness. The blood pressure in the arteries also becomes abnormally low. After a varying period of time the disease invariably ends fatally. Exactly parallel results follow in animals from which both of these minute glands have been removed, except that death, after removal of the second gland, occurs too rapidly for any bronzing of the skin to take place. Removal of one gland, where the difficult surgical operation has been successfully carried out, never leads to death, but if a sufficient interval has been allowed to elapse before removal of the second gland, this is always

found increased in size (hypertrophied), showing that it has taken on the double share of work thrown on it by the removal of the other gland.

Nothing, further than the facts regarding Addison's disease, was known as to the function of this gland until the effects of injecting small doses of an extract prepared from the central portion of the gland (the medulla) into the vein of an animal were demonstrated by Schäfer and Oliver. These observers found that the result of such an injection was an immediate and enormous rise of blood-pressure in the arteries. Careful work showed that this was due to a contraction of the muscular coats of the small arterioles, leading to the capillaries, all over the body. This at once suggested that the function of the suprarenal was to act as a tonic or stimulant for the control of the walls of the small arteries all over the body. Subsequent experiments, as well as the results in suprarenal removal and the low blood-pressure in Addison's disease, abundantly confirmed this view.

Later work showed that the active principle was identical with a substance giving peculiar and characteristic colour reactions, known as the suprarenal chromogen. Thus this substance gives a green colour with salts of iron, and a rose colour with oxidizing agents, such as hydrogen peroxide or free alkalis. Similar reactions are not given by any extract of any other organ in the body. After many painstaking attempts to isolate the active substance had failed, a Japanese scientist (Takamine) had the good fortune to succeed, and named the substance ADRENALIN. It can now be isolated in pure condition from the gland, and be made use of in medicine, but has not yet been obtained synthetically, although closely similar substances have been built up.

Recently it has been shown that adrenalin does not act directly on the muscle-fibres of the arterioles, but indirectly through the peripheral nerve-cells of the sympathetic system, which normally control these fibres. The excitation of these nerve-cells causes them in turn to act upon the muscle-fibres, which then shorten and so diminish the calibre of the blood-vessels, around which they are disposed in a circular fashion. The active material also stimulates other peripheral nerve-cells of the sympathetic system which are not connected with blood-vessels, and it has no effect on blood-vessels not supplied by the sympathetic system, such as those of the lungs.

The exciting effect on the arterioles is so great that these may for a time be entirely closed by its agency. So marked is this effect that when a large dose is given subcutaneously there may result a local gangrene, probably due to failure of blood to the cells in the vicinity of the injection. Thus attempts at subcutaneous grafting of a gland, or a portion of gland under the skin, cause the portion of skin to slough rapidly off as if it were punched out.

It is to its local action in closing up blood-vessels, when used in a properly regulated dose, that suprarenal extract owes its great practical value as a drug, for hitherto it has proved valueless as a remedial agent in the rare Addison's disease, where it might have been thought to have been peculiarly indicated. Whether this be due to its destruction, when

given medicinally, before reaching the blood stream, for it is a peculiarly unstable substance chemically, or whether the failure is due to the impossibility of keeping up a regular and constant supply in similar fashion to the supply from the normal gland, it is at present impossible to determine. This much is known with certainty that it is impossible to keep animals, from which the suprarenal glands have been experimentally removed, alive by injections, at intervals, of adrenalin.

PHYSIOLOGICAL EXPERIMENTS AND ANÆSTHESIA.—Notwithstanding this failure in the more direct instance, the practical applications obtained in surgical operations for adrenalin have more than justified the experiments, and furnish a clear demonstration of how good results in quite unexpected quarters may flow from experimental work. It may perhaps be permissible to point out here how impossible it would be to carry out experiments, either in removing the suprarenal gland or in testing its effects on injection, if the animal were not completely anæsthetized. It would be quite impossible to render an animal so immovable by other means than anæsthesia so as to carry out the former operation, and in the latter, if the animal came out of the influence of the anæsthetic, as is seen in patients recovering after an operation, the blood-pressure would rise from that cause alone, and any struggling of the animal would raise blood-pressure and render the results nugatory. Apart from all humanitarian principles, which are no duller in physiologists than in other human beings, the nature of the work itself demands that there should be anæsthesia during operations in laboratory experiments. The physiologist must be as careful in his operations, and in his post-operative work, as the surgeon is with human patients, if he is to obtain successful results.

From personal observation and experience in many physiological laboratories the writer can testify that less pain is inflicted on laboratory animals than on human beings in medical and surgical practice, for there is no pain or dread previous to operation, such as haunts the human mind before an operation, and the pain inflicted on any animal is trivial compared to that in slaughtering for food, where no anæsthetic is given. No operation more serious than the pinprick of a subcutaneous injection or of the minute cut of a superficial venesection is permitted by law without an anæsthetic, and no more serious operation is carried out in any of the laboratories of the country, which are regularly and frequently visited by inspectors chosen by the Government of the country.

No better instance could be chosen to illustrate the results, often in quite unexpected directions, which flow from such experimental work, than the discovery of adrenalin. No one would have dreamt that work on the physiological functions of the suprarenal glands would have led to discoveries of immense practical value to the operating surgeon in his work, and so to humanity at large. Yet such is the fact, and adrenalin is now in constant use, hundreds of times daily, all over the world, for stopping bleeding which could not otherwise be controlled. A large artery can easily be controlled by the surgeon by tying, or by seizing and crushing with forceps, but the smaller vessels, and especially those running through bony structures, cannot be controlled in this way. It

is not the loss of blood which is the main difficulty here, but the interference with the surgeon's work. The outflow of blood obscures the region being operated on, so that the operator cannot see what he is about, and for this reason he must pause until the bleeding is controlled. If this can only be done by padding the part mechanically, the bleeding is most likely to recommence afresh as soon as the padding is removed. Not only is there delay, but the work is less completely and perfectly performed.

This disturbing effect of bleeding is most troublesome in operations about small cavities, such as the ear, nose, throat, and mouth, and it is here that adrenalin proves such a boon to surgeon and patient alike, in allowing practically bloodless operations to be carried out. The difference between two such operations carried out with and without adrenalin has to be seen to be appreciated. A small pad wetted with some form of cocaine, and with adrenalin in the same solution, is applied to the spot for a few minutes. The cocaine acts as a local anæsthetic and the adrenalin closes off the blood-vessels. Then in a very short time the operative procedures are carried out, there are none of the former frequent moppings to remove blood and examine rapidly in the short period before fresh flowing takes place to see how the work, done more or less clumsily without seeing it, is progressing. The surgeon sees his field of operation all the time, and the work is done quickly and done well. It is true that in a few minutes bleeding occurs as the effect of the adrenalin wears off, but the surgical operation is completed before this commences, which makes all the difference.

In conclusion, the beautiful adaptation between the local anæsthetic and the adrenalin may be pointed out. By constricting the vessels, the adrenalin keeps the cocaine during the operation at exactly the spot where it is required, so that the local anæsthesia is maintained much longer, and there is less drug diffused into the general system. Hence less cocaine serves the required purpose, and there are less developments of those disagreeable general effects of cocaine in excess upon the system. The two drugs together thus form a perfectly adapted system, and have recently been used for much more general operative work where a general anæsthetic cannot for some reason be given, and operations such as the radical treatment of hernia have been carried out with the patient conscious all the time and suffering no pain. All these far-reaching and general practical advantages to humanity have come as applications from what was commenced as a purely scientific investigation, on animals, of the obscure functions of the suprarenal glands.

THE THYROID GLAND.—As another instance we may give a sketch of the work done on the functions of another ductless gland called the thyroid gland. The gland obtains its name from its position close to the thyroid cartilage ("Adam's apple") in the neck. It is a paired structure, lying alongside this cartilage, the two halves being united by a thin bridge of tissue at the upper end. A peculiar jelly-like (colloidal) material is secreted by this gland and poured into the blood-vessels

This material is seen, in sections of the gland under the microscope, in rounded masses of varying size, which are always surrounded by a single layer of cubical secreting cells.

Two sets of diseased conditions are found in medical practice, associated respectively with deficiency or excess of this secretion, which present a marked antithesis to each other. Two sets of tissues are kept in chemical control by the secretion of the thyroid, namely, the central nervous system, and the skin and subcutaneous tissues. At first sight there seems little in common between these two systems of tissues, but in the development of the young embryonic animal they arise from the same set of cells, and later in life the skin and its modifications, and the peculiar epithelial structures of the special senses, form the external field, so to speak, of the central nervous system to and from which the greater volume of nerve impulses are daily sent. So that there is a closer connection and inter-relationship between the cutaneous areas and the brain and spinal cord than might at first sight be imagined.

CRETINISM.—The results of defective thyroid secretion may be first considered. The defect in the secretion may be only partial or almost complete, and it may occur congenitally or arise later in life from some pathological change associated with degeneration of the secreting structures of the gland. When there is great congenital deficiency of the thyroid, the peculiar and interesting condition known as cretinism occurs. This disease occurs sporadically, isolated cases being seen here and there, but it is a remarkable fact that, like another disease associated with excessive growth of the thyroid, called Derbyshire neck or goitre, it is found endemic in certain districts, the districts not being coincident in the case of the two diseases. The diseases, or the increased tendency to their development, are also due to something peculiar to the district, for cretins do not produce cretins on removal from the district, and, conversely, healthy parents coming to reside in a cretinous district may have cretins for offspring. Goitre is supposed to be associated with an excess of calcium salts in the drinking water, and cretinism with sunless valleys, since it is found in inhabitants of deep alpine valleys, but the subject requires investigation, and it will probably be found that one cause is the converse of the other, a natural excess of some food constituent, organic or mineral, in one case and a deficiency in the other.

No one who has seen a typical cretin could ever mistake the condition for another, so typical is the whole picture produced by the absence of this small, inconspicuous gland in the neck. The cretin is a short, stout, misshapen dwarf, clumsy in body and mind. The face is broad and expressionless, the folds of the skin being almost absent or misplaced. The head is also broad, and the hair dry and scanty. The eyes lack lustre and expression, and betray the idiocy of the mind. The hands are large and clumsy in shape, and the fingers broad and stub-ended.

Thus there is absence of normal development of both body and mind, all through the absence of this one internal secretion from a gland not weighing over 2 oz. in a normal adult human being. Short

of this typical picture there are seen children of feeble and stunted development of body and intellect, who could not be described as cretins, and yet are suffering from deficient thyroid secretion, and these form a fair proportion of the class known as backward and mentally deficient children.

MYXŒDEMA.—Deficiency of thyroid secretion occurring late in life, after growth is complete, cannot, of course, stunt the bony skeleton or cause such an arrested development of mind; but on the whole the conditions observed bear a close resemblance in other respects to cretinism. The disease is then known as myxœdema, and occurs more frequently in women than men, like its opposed condition of goitre.

Some of the appearances of myxœdema are illustrated in the Plate A CASE OF MYXŒDEMA, which also shows the improvement obtained in such cases on treatment with fresh thyroid gland by the mouth. The most marked symptoms are a notable increase in the general bulk of the body, due chiefly to an overgrowth (or hyperplasia) of the subcutaneous tissues, which swell under the skin and give this a puffed appearance. The swelling is inelastic and solid in character, and does not pit on pressure with the finger like the œdema of kidney disease. The hair and skin become very dry and rough. As a result of these changes the features look coarse and broad, the lips thick, and the mouth enlarged. The face loses its expression, and there is a striking slowness of thought and motion, and a heavy, slow gait. The memory becomes defective and the mind vacant, so that the patients lose at intervals recollection of what they are engaged in doing or where they may have been going. They become irritable and suspicious of those about them, and there may be delusions and hallucinations leading in some cases to final dementia. The body temperature is usually subnormal, and all the symptoms are aggravated by exposure to cold, against which such patients possess a much lowered resistance.

Before the important functions of the thyroid were completely understood, the gland was removed in man when diseased, and in a fair number of such cases a condition known as OPERATIVE MYXŒDEMA developed, which closely simulates the naturally occurring myxœdema sketched above. This condition occurred more frequently in younger persons, just as the symptoms following removal in animals are more pronounced in the case of younger animals and may be lacking in old animals.

It had been noticed that removal in the dog was usually rapidly fatal, but without the characteristic symptoms of myxœdema, while a similar operation in herbivorous animals was not attended by fatal results. It was then shown by Horsley that removal in the case of monkeys gave a more prolonged clinical history than in the case of dogs, and that typical myxœdema was produced. Further, if the monkeys were kept very warm, this more acute myxœdema was averted, and a condition of a more chronic type ensued, closely resembling cretinism.

It was thus established that myxœdema and cretinism in man were probably due to defective secretion of the thyroid, and the application

of this knowledge in the treatment of these diseases has proved one of the finest achievements of modern medicine. As Osler puts it in his *Textbook of Medicine*: "Our art has made no more brilliant advance than in the cure of these disorders due to disturbed function of the thyroid gland. That we can to-day rescue children otherwise doomed to helpless idiocy—that we can restore to life the hopeless victims of myxœdema—is a triumph of experimental medicine for which we are indebted very largely to Sir Victor Horsley and to his pupil Murray. Transplantation of the gland was first tried; then Murray used an extract subcutaneously. Hector Mackenzie in London and Howitz in Copenhagen introduced the method of feeding. We now know that the gland, taken either fresh or as the watery or glycerin extract, or dried and powdered, is equally efficacious in a majority of all the cases of myxœdema in infants or adults.

"The results, as a rule, are most astounding—unparalleled by anything in the whole range of curative measures. Within six weeks a poor, feeble-minded, toadlike caricature of humanity may be restored to mental and bodily health. The skin becomes moist, the urine is increased, the perspiration returns, the temperature rises, the pulse rate quickens, and the mental torpor lessens.

"The treatment, as Murray suggests, must be carried out in two stages—one early, in which full doses are given until the cure is effected; the other, the permanent use of small doses sufficient to preserve the normal metabolism."

GOITRE.—In the disease known as EXOPHTHALMIC GOITRE the clinical picture is an almost exact antithesis to that seen in cretinism or myxœdema. The mental temperament is quick, neurotic, and most excitable, in contrast to the dull apathy and listlessness of the other condition. The heart beat is much more rapid than normal, in place of the very slow beat of myxœdema.

The skin is flushed and moist, and the temperature tends to be above normal, instead of the dry, rough skin and low temperature caused by defective thyroid secretion. Further signs of the disease are a fine tremor of the voluntary muscles, enlargement of the thyroids, which often are pulsatile, and a prominent, standing-out, staring appearance of the eyeballs which strikes one at first sight and gives the name to the disease. The histological appearance of sections of the gland confirms the impression of over-secretion of thyroid in this affection, and further proof of this is found in the results of feeding with thyroid gland in normal individuals, or of excessive administration in myxœdema after the first stages, when practically all the remarkable set of symptoms described above can be reproduced.

Administration of thyroid in exophthalmic goitre is worse than useless, since it but adds more fuel to the fire by increasing an already excessive secretion and aggravates all the symptoms of the disease. Partial removal of the gland has been attempted, but the surgical dangers are so great that this operation is no longer in favour. The unavoidable manipulations of the operation appear to stimulate the gland to increase still more its

A CASE OF MYXŒDEMA

Before and after treatment with thyroid glands of the sheep.

To illustrate a disease due to failure of secretion from a small gland in the neck, and to show the dependence of one part of the body upon the sympathetic working of another.

A CASE OF MYXŒDEMA

already superabundant secretion; death under the anæsthetic is a frequent occurrence, and, if this danger be passed successfully, in the few days after the operation there often sets in an exaggeration of the symptoms leading to delirium, prostration, and finally to a fatal issue.

Attempts at medical treatment have been made, but, except for palliative treatment of symptoms, have not been very successful or given permanent or certain results. More radical attempts have been made by administration of serum or milk from goats deprived of their thyroid glands, and by attempting an anti-serum obtained by injecting thyroid in animals on the same lines as in preparation of anti-sera, but hitherto the results have not been encouraging.

PITUITARY GLAND.—Another of the ductless glands, called the pituitary body, is lodged in a bony pit in the base of the cranial cavity called the SELLA TURCICA. This minute gland is in some obscure way connected with the nutrition of the bones, for when it is pathologically altered and hypertrophied a very rare disease called ACROMEGALY arises which is curiously associated with a very great overgrowth in the bones, chiefly of the jaw and of the hands and feet. The overgrowth may affect the thorax also, giving rise to a most distorted appearance, and the skeleton in parts looks like that of a giant. There are two distinct parts to the pituitary gland, which are quite different both in their minute structure and in their physiological effects. The anterior lobe produces a substance which raises the blood pressure, but in a distinctive manner to the rise given by suprarenal extract. Extracts of the gland have also the effect of increasing the flow of secretion of urine from the kidneys, and it would therefore appear to furnish a chemical excitant, or hormone, for the kidneys.

THE SPLEEN.—The remaining ductless gland is the spleen. Although this gland is much larger in size than the other ductless glands, it may be completely removed without causing death or even any profound modification in health in normal animals, and its functions at the present time are very imperfectly understood. In certain diseases it becomes enormously enlarged, and then its removal becomes dangerous and has led to fatal results, pointing out that it may possibly be an organ which takes on more important functions under diseased or pathological conditions, but that in conditions of health its functions may be vicariously discharged by other organs.

INTERNAL SECRETIONS OF PANCREAS.—The ductless glands are not the only organs which yield chemical excitants for other tissues. We have already noticed one example of such chemical sympathy in the SECRETIN yielded by the upper part of the intestine for the stimulation of the secretory activity of the pancreas. The pancreas itself in turn yields an internal secretion which passes into the blood and stimulates the liver cells in the storage of the absorbed carbohydrate. Complete removal of the pancreas leads to a severe and rapidly fatal form of diabetes, and naturally occurring disease of the pancreas, sufficient in extent to alter the whole of the gland and pervert its functions, similarly gives rise to fatal diabetes. Stoppage of the pancreatic secretion from entering

the intestine, by ligature of the ducts, does not lead to this result, showing that the diabetes is due to failure of something normally thrown into the blood by the gland.

These examples illustrate the general law that there is a very broadcast and well-nigh universal chemical sympathy between the various organs and tissues of the body, necessary for the well-being and common life of the whole organism.

CHAPTER VI

THE CENTRAL NERVOUS SYSTEM

We may now pass from these chemical considerations to a sketch of the general control by the nervous system, and the arrangement and distribution of nerve-cells and fibres for this control, which affects all parts of the whole organism.

The autonomic or sympathetic system, which is placed outside of direct control of the will and consciousness, and has charge of the more direct visceral and nutritive life of the animal, has already been mentioned in dealing with digestion, and we shall now consider the outlines of the physiology and anatomy of the central nervous system, consisting of the brain, spinal cord, and peripheral nerve-trunks and fibres, which regulates, controls, and co-ordinates the conscious and voluntary acts of the animal.

BRAIN AND SPINAL CORD.—The brain and spinal cord are exceedingly delicate structures which for protection against mechanical injury are completely cased in bony structures or chambers formed by the bones of the skull and the backbone or vertebral column. The weight of the brain is borne by the bones forming the base of the skull, and the cranial cavity is arched over and completely covered in by the frontal, parietal, and occipital bones, which form the vault of the skull. There is a large opening in the occipital bone, in which lies the medulla oblongata or expanded upper end of the spinal cord connecting together the brain and spinal cord. The spinal cord is protected by the neural rings of the vertebræ or series of bones forming the backbone. These neural rings form laminæ or plates, which imbricate, or overlap one another, forming in this manner a complete and slightly flexible canal in which the spinal cord lies and is protected from injury.

CRANIAL AND SPINAL NERVES.—The brain and cord are placed in physiological continuity with the periphery, including skin, muscles, special sense organs, viscera, and, in fact, all the tissues of the body, by means of a paired system of nerves or nerve-trunks which pass through openings called foramina (L. *foramen*, a hole) in the skull, and between the successive vertebræ. There are paired openings in the skull for the twelve pairs of cranial nerves, and similar openings between the successive vertebræ for the spinal nerves. Each nerve-trunk on the two sides arises symmetrically by two roots called respectively the motor or efferent root and the

sensory or afferent root. These two roots soon unite to form the mixed nerve-trunk, which contains fibres from each root inextricably blended. The afferent root is composed of nerve-fibres which carry impulses in toward the centre, and the efferent root of fibres which carry impulses outwards to the periphery. In the nerve-trunk the two types of fibre run in parallel lines, and cannot be distinguished by appearance. As the trunk is traced towards the periphery it divides and redivides as it nears the area it supplies, until fine twigs are formed quite invisible to the naked eye, and finally it is distributed as individual fibres which come into physiological relationship with the structures which are to be actuated by the efferent fibres, or, vice versa, to the structures which are to actuate the afferent fibres and start impulses in towards the central nervous system. Except in a few unavoidable situations, such as the well-known example where the ulnar nerve passes the elbow, the nerve-trunks are situated deeply and protected by the soft tissues, and in addition there are protective sheathing coats.

MINUTE STRUCTURE OF NERVOUS SYSTEM.—The minute structure of the nerve-fibres and of certain of the peripheral nerve-endings has already been mentioned in connection with the description of the Plate FORMS OF ANIMAL CELLS, figs. 16–19. In the brain and cord two types of tissue are obvious to the naked eye, when sections are made, which from their naked-eye appearance in the cadaver are called the GREY and WHITE MATTER.[1] Microscopic examination shows that this difference in appearance is due to the presence in the grey matter of large numbers of nerve-cells lying close together and connected by the short processes known as DENDRITES (fig. 17), while the white matter consists, like the peripheral nerve-trunks, solely of nerve-fibres arranged in a parallel fashion.

NERVE IMPULSES.—Accordingly the grey matter is the part where impulses originate or are co-ordinated together, and the white matter forms the conducting paths for the impulses, by which one part of the system is placed *en rapport* with other parts.

To take an analogy from the distribution of a telegraphic or telephonic system, the white matter represents the bundles of wires traversing the country or district in all directions, while the grey matter represents the telephone exchanges, or telegraph offices, where messages are received, transcribed, and redispatched in different directions.[2]

The positions of the grey and white matters are reversed in the brain and spinal cord. In the spinal cord the grey matter, with its cells, lies centrally, and the white matter surrounds it, the long fibres running parallel to the length of the cord, and carrying impulses up and down between centres in the grey matter at various levels in the cord, and to and fro between the cord and the higher centres in the brain.

The evolution of this relative distribution of grey and white matter in

[1] During life and immediately after death the grey matter is pink in colour, from its large blood supply. The grey colour is a dissecting-room appearance.

[2] It may not be carrying the analogy too far to add that the chemical system of correlation and stimulation, described in previous pages, is like the somewhat slower postal system, the hormones, or excitants, being the postmen with the letters for the different tissues.

brain and cord shows an admirable adaptation to the functions to be carried out by the different parts. The number of nerve-cells required for the work to be done is many times greater in the brain than in the cord, especially in the higher mammals and in man, the degree of skilled co-ordination evolved requiring a very large number of cells, while the lowlier types of co-ordination in the cord require fewer cells. At each level, nerve-cells are only required belonging or proportional to the number of nerve-fibres going out by the nerves at the given level in the cord. Further, all the nerve-cells must be connected up with one another. The only simple and effective way in which this can be done, and the nerve-cells connected properly up, where there is a large number of cells, is by arranging them in a not too thick layer on a surface, in a manner somewhat like the numbers on a telephone switchboard.

In the grey matter of the brain the cells are several layers thick, unlike the single layer of connections on the switchboard, but it is obvious that the number of layers cannot be too great, or there will not be space for the fibres and dendrites connecting the cells together, and also for the fibres coming in from other distant centres. Hence it is obvious that it is necessary to provide as large a surface as possible for the proper arrangement of the cells; this object is achieved by placing the grey matter peripherally, or in the CORTEX as it is called, and it is also for this reason that the brain cortex is corrugated all over with elevations or convolutions, separated by hollows or sulci (see figs. 435 and 436).

PARTS OF THE BRAIN.—The brain and cord are bilaterally symmetrical on the right and left sides, and the two sets of nerve-cells on the two sides are connected up by fibres at the same level, called commissural fibres, so as to place them in accord with each other. The chief parts of the brain are the cerebral hemispheres, or CEREBRUM, forming the greater brain; the cerebellar hemispheres, or CEREBELLUM or lesser brain; the BASAL GANGLIA, lying on the track of the fibres between cerebrum and cerebellum; and the MEDULLA OBLONGATA, connecting brain and cord. The two cerebral hemispheres are separated above by a deep longitudinal cleft or median fissure, and are united at the base of this cleft by a great commissural band of fibres called the CORPUS CALLOSUM. A similar great commissure, called the PONS CEREBELLI, unites the two cerebellar hemispheres.

CO-ORDINATION.—The most fundamental property of this vast and complex system of nerves and nerve-fibres is its power of co-ordinating the nerve impulses in a most delicately balanced fashion, so that all the operations of the animal's life are carried out in a just and true proportion. The amount of this co-ordination and its degree of complexity are integrated up in the system, as higher and higher centres become involved, up to the upper limits of conscious thought and skilled purposeful acts. Even the simplest muscular movement involves the co-operation of a large number of different nerve-cells, each playing in during the act in most exactly balanced proportion.

MUSCULAR TONICITY.—Even when the muscles are quiescent, and no muscular movement is being carried out, they are all constantly receiving

impulses from the nerve-cells along the nerve-fibres supplying them, and impulses are as continually being sent in from the afferent or sensory endings lying amidst the muscle-fibres towards the nerve-centres in the spinal cord and brain. As a result, the muscles are all the time on the *qui vive*, in a state of muscular tonicity as it is called. The degree of this tonicity is nicely regulated by the strength of the impulses passing to and from the nerve-centres. It is the degree of this tonicity which is estimated by the physician when he tests the knee-jerk, the time between the tapping of the kneecap tendon at the knee and the kick out of the leg being far too short for the impulses to pass up to the cord and back again in what is called a reflex, so that the name TENDON REFLEX is a misnomer. The knee-jerk, by its degree, shows the amount of tautness (or tonicity) in which the muscles are being held by the nervous system, and so gives a sign for estimating the condition of the nerve-cells and connections.

RECIPROCAL INNERVATION.—Hence, when a muscular movement takes place, however simple, such, for example, as the bending of the arm at the elbow, we have to picture, not a simple impulse sent to the biceps muscle lying at the front of the upper arm, but rather a heightening of the tone of the biceps muscle, and a depression of the tone of the opposing set of muscles at the back of the arm. This holds for every muscular movement in the body, and the principle that when in any movement the tonicity of one set of muscles is increased, the tonicity of their opponents is decreased in corresponding degree is called RECIPROCAL INNERVATION. In such reciprocal innervation there are to be taken into account not only the two sets of efferent impulses outwards to the muscles, but also the two sets of afferent impulses inwards to the centre informing it, if the expression may be allowed, how the movement is progressing, and what is the degree of resistance to it, so that the strength of the efferent impulses may be regulated accordingly.

ARRANGEMENT OF NERVE-CELLS IN THE CORD.—To carry out accurately this complicated process it is necessary that the nerve-cells at the centre in the cord should not be arranged in a haphazard way; they must be arranged definitely in position in regard to one another, and have definite connections by commissural fibres with one another. The necessity for perfect arrangement and co-adaptation becomes enormously increased as the skilled nature of the muscular act is further developed and we reach the highly skilled movements possessed by man. There is hence a very highly developed topographical relationship of parts involved together in co-ordinated movements, and the degree of this increases as we ascend the scale through the mammalia to man. Such a primary arrangement is carried out in the cord itself, at the various levels where the nerve-cells lie, for the different sets of muscles usually acting together. As a result, the lower centres usually carry out a good many co-ordinated movements without the brain and consciousness being called into operation. Examples from many which may be given of this are the continuance throughout life of the movements due to the muscles involved in the act of respiration and the reflex movements of the eyelids.

Many acquired co-ordinated movements, such as those of walking, cycling, swimming, once they have been acquired, become fired off automatically by the lower centres in brain and cord, and only require to be regulated in intensity, commenced, and terminated from the higher centres in the brain.

CEREBRAL LOCALIZATION.—The same spatial arrangements are carried out in the brain by what is known as CEREBRAL LOCALIZATION, the areas for special senses, and for voluntary movement of different limbs and sets of muscles, being located in separate areas, which are called the cerebral areas or sensori-motor areas, for these senses and parts of the muscular system (see figs. 435 and 436). This localization has been studied by such experimental methods as removal of certain circumscribed areas of the cortex, followed by observation of the areas of the body paralysed for voluntary movements as the result of the operation; as also by stimulation of the areas electrically, and observation of the

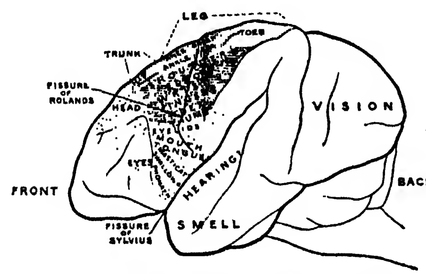


Fig. 435.—Left Side of Brain of Monkey showing Motor Areas. See text.

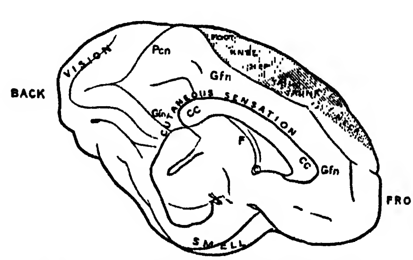


Fig. 436.—Middle Internal Aspect of Brain of Monkey showing Areas of Localized Function

movements of co-ordinated sets of muscles in a definite fashion which result from the stimulation.

The localization is very precise, and a person skilled in such knowledge can produce a certain co-ordinated movement and predict its occurrence on stimulation with as great accuracy as a pianist can strike a definite chord on the piano. Irritation of a particular area, by a growth or by pressure in some other way, as by a depressed portion of bone from an accident, causes similar movements or paralysis, or may cause Jacksonian epilepsy, in which the attack is preceded by twitchings of a definite kind belonging to the area primarily affected. Cerebral surgery has been much advanced by such study, and the surgeon is now able to locate and successfully attack lesions in a manner which could not formerly be attempted.

EPILEPSY AND PARALYSIS.—It is interesting to note that epilepsy of the Jacksonian type can be imitated by electrical stimulation; thus, for example, if the thumb area be gently stimulated, movements of the thumb are obtained of a definite type; if the strength be increased, the stimulation travels to neighbouring areas in the cortex, and the character of the thumb movements alters; with a somewhat stronger stimulus the forearm is affected, then the whole arm, then both arms, then both arms and legs, and finally, with a still stronger stimulus, the whole muscular system is set in motion. This is precisely what happens in epilepsy, which first begins at a very localized centre, and then irradiates till it involves the

whole cortex. In the case of epilepsy due to a local injury it is hence important to notice where the movements commence, in order to locate the exact site of the mischief, which can then be exposed, examined, and treated.

Similarly, in cases of paralysis from cerebral hæmorrhage, or other interference with the blood supply of the brain, the areas affected in the brain are shown by the areas of the body paralysed as a result of the lesion.

NERVE-TRACTS.—Not only is there a definite location of the nerve-cells, but also in the case of the nerve-fibres of the white matter it has been found that these run in definite parts in the brain and cord which are called TRACTS. These tracts have been definitely followed out with infinite care by many observers, by such methods as following out the nerve-fibre degenerations which follow the cutting across of certain areas. Thus, if the leg area in the cerebral cortex be removed, and, after allowing ten days to a fortnight to ensue for degeneration of the nerve-fibres belonging to the removed cells to occur, sections can then be made, and appropriately stained, across the brain and successive levels of the cord, the degeneration and its course can be mapped out right down to the area of distribution in the lower part of the cord where the nerves passing out to the leg originate. It is interesting that in their course, at the medulla oblongata, the majority of the fibres pass to the opposite side of the cord. Hence if, say, the leg area of the cortex be removed on the right side of the brain, it is the left leg which is most paralysed. This decussation, as it is called, occurs for all the muscular areas, and has to be remembered in cases of hemiplegia or paralysis of one side of the body due to cerebral injury.

It may be stated in general terms that the tracts of conduction of impulses from the brain down to the cord are situated in the more anterior portion of the white matter of the cord, while the so-called sensory tracts, which carry impulses from the periphery and lower regions of the cord up towards the brain, are in the more posterior portions of the white matter of the cord. When a nerve-fibre is cut across it is the part cut off from the nerve-cell which rapidly degenerates, like a branch cut off from a tree. Since the motor tracts coming from the brain have their nerve-cells above, and the sensory tracts going up to the brain have their nerve-cells below, it follows that the motor tracts degenerate below any lesion in the cord, and the sensory tracts above any lesion; hence the former are often called descending and the latter ascending tracts. It is obvious that in this fashion the various tracts and their connections can be followed through their courses and connections.

This has now been done for most of the important conducting paths and groups of nerve-cells, and the results obtained have been of great service in the diagnosis of obscure nervous diseases.

CLINICAL OBSERVATION.—Conversely, the patient clinical observation of cases of nervous diseases has been of great assistance to the neuro-physiologist in following out the maze of nerve-cells and conducting tracts which the central nervous system presents, or has supplied valuable con-

firmations of his experimental findings. For example, the physiologist finds that section of the posterior portions of the spinal cord leads to loss of sensation in the parts below the section, but not to loss of power of movement of those parts; and in the disease known as LOCOMOTOR ATAXY or TABES DORSALIS the clinician finds that there is a loss of sensation, and it is found post-mortem that the posterior tracts are degenerated.

FORMATION OF NEW TRACTS.—An interesting fact in relation to injury of the nervous system, producing artificial alteration of its relation to its peripheral connections, is the power of finding out or building up new paths of co-ordination. This is seen, in the case of injury, in the gradual return—partial or complete—of power of movement after paralysis. The normal track is the easiest one, but, when this is destroyed, new, more roundabout ones are discovered and made use of, and partially replace the old ones.

Again, when a nerve is cut across by an accident, if the ends are brought together by a suture, regeneration occurs, and the fibres grow down the old sheaths and make connections with the old endings. Even different nerves may be united crosswise to each other, and on stimulation of nerve A the endings in B respond. Here there must obviously be a rearrangement to a large extent of co-ordinations in the centre for co-ordinated movements to be successfully carried out; but in time these are acquired and put in operation.

TENDON GRAFTING.—Similar results, of the greatest practical importance, are seen in the modern operations of tendon grafting or TENOPLASTY, which have recently revolutionized certain domains of orthopædic surgery, and have enabled the surgeon successfully to combat the deplorable effects of such injuries as result from infantile paralysis and deformities of the feet and lameness from other causes. In this operation the tendon of a paralysed muscle is grafted on to the tendon of a sound muscle, the tendons being lengthened by partial splitting and reversal, or even joined by silk sutures. The remarkable thing is that very often the tendons and muscles joined are such as normally act in an opposite sense, that is to say, one may be an extensor and the other a flexor of the joint, so that it might be thought that movement would become confused and impossible, an attempt to flex leading to extension and vice versa. But in a short time, and almost unconsciously, the new set of co-ordinations becomes acquired, and a useful limb instead of a useless burden and deformity, is the result.

NERVE POISONS.—The chemical effects of nerve poisons on the balanced co-ordination of the nervous system are also most striking and interesting. Thus the convulsive spasms of strychnine poisoning have been shown to be due to the drug in some way breaking down the normal resistances in the reflex arc, so that any feeble stimulus arriving by the sensory path, instead of producing only a proportionate effect, gives a maximum motor response. Thus, merely blowing gently on a strychnized frog produces a tetanic convulsion. That it is the spinal cord, and not the muscles directly, which is affected, is shown by the

fact that the convulsions do not occur when the cord is destroyed; but further, if the skin is made completely anæsthetic by cocaine, the convulsions again do not occur. It is hence clear that slight influences from the skin, which normally have a resistance opposed to them and cannot evoke a muscular response, now have full play, and the muscular response must invariably follow their arrival. In other words, the response co-ordinated between afferent and efferent impulse now no longer holds true.

TETANUS, OR LOCKJAW.—The manner in which the virus of tetanus produces its peculiar effects upon the muscles in lockjaw has quite recently been elucidated in a most brilliant manner by Sherrington, who has shown that the effect in lockjaw is due to the tetanin interfering with muscular co-ordination in such a way as to actually reverse the normal relationships, and produce the antagonistic action when the motor cortex in the brain is stimulated. The result is that when the affected animal or individual tries to relax or open the jaw, he only the more effectually tightens or closes it, and thus causes the locking effect.

The virus of this disease flourishes and travels in a most peculiar manner in the nerves. If a minute quantity, less than a milligram, of the virus be injected into a peripheral nerve it remains confined to the nerve and does not diffuse into other tissues, but it slowly travels up the nerve, reaches the cord, and as slowly travels up to the cerebral cortex. In some time, it may be a week or more, the animal exhibits the typical lockjaw, which comes on in one side earlier than the other.

If now the animal be anæsthetized, and the area of the cerebral cortex which governs the jaw movements be exposed and stimulated, it is found that stimulation of that area which normally provokes a dropping of the jaw, and which still does so in the unaffected side, now causes the jaw to be raised and forcibly closed.

CHAPTER VII

RADIOACTIVITY AND RADIUM

In the previous pages many instances have occurred showing the extent to which advance in medical and surgical science is dependent upon collateral and contemporary advance in the more fundamental sciences of chemistry and biology, and the intermediate sciences based on these of bacteriology, bio-chemistry, cytology, &c. To the services already mentioned of physical chemistry may here be added the contributions of organic chemistry in the synthetic preparation of many most valuable drugs, such as the valuable hypnotics or sleep-producers and analgesics or pain-allayers of synthetic origin; the febrifuges, such as antipyrin, phenacetin, and similar bodies; the organic antiseptics, such as salol; and the salicylates, of such service in acute und chronic rheu-

matism. At the present time advance in this field is being made in the synthesis of organic compounds of the heavy metals, which are proving more effective and controllable than the more poisonous inorganic salts hitherto in almost exclusive use. Mention may also be made of the combinations of bromine and iodine with fats and protein, which are daily coming more into use in cutaneous affections.

PHYSICAL ADVANCES.—To the science of experimental physics, no less than to chemistry, the medical sciences owe no mean share of the progress they have made in reducing human suffering. Without the discovery of the compound microscope, and the continued perfecting of its parts by the optician, the experimental study of the cell could never have reached the position it now holds, and the continual debt the ophthalmic surgeon is under to optical discoveries needs no amplification of statement to anyone who has had his eyes tested for errors of refraction in recent times.

RÖNTGEN RAYS.—More recently, however, the discoveries of new forms of radiant energy in the physical world have opened a new and still progressing chapter in diagnosis and treatment in both medicine and surgery. The beginning of the interest to medical science in these new discoveries dates from the fortunate and accidental discovery of Röntgen, that the rays which now bear his name were unable to penetrate the calcium salts of the bones, and hence gave a photograph of any portion of the bony skeleton interposed on the course of the rays to a photographic plate, shielded in the ordinary way from light rays by the usual wooden back of the plateholder.

Röntgen discovered that when an electric discharge of high frequency of alternation is passed between electrodes in a tube with a high vacuum, a form of ray is given out from the negative electrode which has the power of affecting a photographic plate. These rays, moreover, have the power of penetrating many substances, such as wood, cloth, and vegetable textile fabrics, which are opaque to ordinary light rays, while metals are opaque to the rays, and hence a shadow photograph of the outline of any metallic object can be obtained by interposing it between the vacuum tube and the photographic plate. If the opacity had been confined to metallic objects, the interest in X-rays might have been long confined to the domain of pure physics, but, the hand of the operator having also been interposed, it was soon discovered that the bones of the hand also became photographed, the soft-tissued skin being much more transparent, and it was soon realized that this property, which was at first a scientific curiosity, might be of great service in surgery where bones were injured, broken, or badly set, and also, on account of the opacity of metallic bodies, in locating foreign bodies, such as needles, coins, and bullets, which had accidentally become causes of injury.

From this simple commencement the discovery has grown, and is still growing, in importance of practical application every year. The development has taken place along two distinct lines, viz. of diagnosis and of treatment. The discovery of the action on living tissues, which caused the rays to be used in medical treatment, also came in an accidental way,

rather painful to the operators themselves, and giving rise at first, before the matter was understood, to accidents, called X-ray burns, in both patients and operators. When the tissues are exposed for too long periods, or too frequently, to the rays, painful and very slowly healing ulcerations of the skin and underlying tissues occur. These injuries, in the case of certain X-ray operators, have proved intractable, and in one or two cases have ended fatally, the effect somewhat simulating malignant disease. At the present time those who have much to do with X-ray work use gloves impregnated with salts which are opaque to the rays (*vide infra*), and in the case of the patients a due amount of exposure only is applied, and the parts not to be acted upon are protected by metallic or other screens containing salts opaque to the rays. As a result of the experience thus dearly bought, accidents such as occurred in earlier days are now extremely rare, and should be altogether avoidable.

On account of the extreme practical importance of the X-rays, the development of the accessory apparatus for their production (such as coils, static induction machines, vacuum tubes, interruptors for the coils, and fluorescent screens) has been very rapid, and the results now obtained are very different from those of but a few years ago.

One of the most important steps forward was the discovery that screens impregnated with certain salts, such as the salts of barium and thorium, fluoresced strongly when the rays fell upon them. Hence such screens could be used instead of photographic plates, and there was no longer any need to wait for the development of plates, and the various parts could be viewed at once, in actual movement, and from different aspects.

It was also soon discovered that, although the bones were the least transparent, from their high content in calcium salt, yet other parts of the body varied in transparency, even in the normal condition, and under certain pathological conditions there was a decrease in transparency which made the altered diseased tissues visible. This brought the rays into use for many other diagnostic purposes than disease of the bones and detection of foreign metallic bodies.

Diagnosis by Röntgen Rays.—The disease of all others in which an early diagnosis is indispensable from the point of view of treatment is pulmonary tuberculosis, and here X-ray illumination has in recent times done great service in the hands of skilled experimenters. It is well known that tuberculous areas tend to deposit in their later stages calcium salts, or to undergo calcareous degeneration as it is called; but, long before there is any actual deposit, the amount of calcium salts in the tissues of a tubercle becomes increased, and this increase renders even a small and early mass of tubercle less transparent to the X-rays than normal tissues. It has been found in many doubtful cases of phthisis that an X-ray examination, or X-ray photograph, displays small nodules of tubercle before anything can be found by a clinical examination of the chest, and an early diagnosis can often be settled in this way and treatment started sooner, so giving a much greater chance of stopping the progress of the disease.

Renal calculi can also often be detected by the rays when their

presence cannot be conclusively shown by other symptoms or modes of examination; biliary calculi are less opaque than renal, and here the X-ray examination has hitherto proved less satisfactory. The heart and its beating, as well as the aorta and other great vessels attached to it, are also clearly shown by a good X-ray illumination, and aneurisms can be discovered and located in this way; arteries in a condition of calcareous degeneration are also made apparent by their increased opacity. The comparative amount of movement of diaphragm and ribs on the two sides is also made apparent, and this is often of service in the detection of pulmonary disease. The intestinal tract can also be brought clearly out by the administration of calcium salts, and in this way the movements of stomach and intestine have been studied, both by the physiologist and the clinician.

RADIUM TREATMENT AND FINSEN LIGHT.—As a therapeutic agency the X-rays have been most effective in the treatment of cutaneous diseases, no effective means having yet been devised by which they can be brought properly to bear with sufficient intensity on lesions in the deeper tissues. In those most serious diseases affecting superficial tissues which have hitherto proved most intractable to ordinary therapeutic agents and surgical interference, such as epithelioma, rodent ulcer, and lupus (or tubercular disease of the skin), radioactivity, either in the form of X-rays, radium treatment, or Finsen light, has in many cases proved valuable.

There does not appear to be much difference in the mode of action upon living tissues or organisms of radium and X-rays, and, as the latter are more controllable in intensity of action, they are now, of these two agents, used almost exclusively in the treatment of the above cutaneous diseases. The Finsen-light treatment consists in concentrating, by means of a water lens (with water circulation which absorbs the heat rays to a large extent), the light rays from a powerful arc light at a distance of a few inches, upon the diseased area of skin. The remedial effect seems to be chiefly due to the ultra-violet rays, and attempts are made to increase the effects by painting the skin with fluorescent solutions, such as eosin, fluorescin, &c.

EFFECTS OF SUNLIGHT.—There is no doubt that radiant energy in different forms has a profound effect upon living matter. For example, the whole world of living things is dependent for its energy supply and very existence upon the activity of the chlorophyll, or green colouring matter, of the plant under the influence of sunlight. The chlorophyll-containing cell then acts as a transformer for turning the solar energy into the chemical energy of the organic substances of the plants, and on this chemical energy of the plant substances the whole animal creation is directly or indirectly dependent. All the disease organisms of the bacterial class are minute plant structures of the fungoid type, which possess no chlorophyll-forming powers, and hence cannot utilize solar energy, but must, in a parasitic way, obtain the energy for carrying on their existence by using organic food, or chemical energy provided by higher animals or plants. Not only is sunlight unnecessary for the processes of their life, it is actually inimical to its continuance, for

most bacteria are rapidly killed when exposed to direct sunlight. The sun is hence one of the most potent health agencies we possess, and the recognition of this fact by the sanitarian, and the consequent removal of dark alleys and sunless rooms in the slums of our great cities, is largely responsible for the decrease in the death rate due to phthisis and other diseases air-borne by bacteria, which we shall presently consider.

A moment's consideration of the life habits of all bacteria in their hosts shows that they live deep under the surface in throat, lungs, intestine, or other internal organs, where light never reaches them, or other form of radioactivity. If they could be brought to the surface and exposed to different forms of radioactivity, including sunlight, they could readily be destroyed. Just as the parts away from the light in the body harbour most the bacteria of disease, so in our dwellings and habitats those parts to which light, and, it may be added, air and oxygen, have least access, are most highly infectious and dangerous, for here the bacteria exhaled from the inmates grow and flourish.

The effects of sunlight on the skin in producing bronzing and sunburn, show that there is a radioactivity in the sun's rays apart from their purely heating effect, which has a profound action upon the animal organism. The stimulating effects of direct or indirect sunshine are absolutely essential to a healthy existence, the first effects of a deprivation being the production of an anæmic condition.

In this connection it is worth while to reflect on the fact that the blood is coloured, and this must have some relationship to light absorption. Further, it has been shown that there is a chemical relationship between the green colouring matter of the plant and the red colouring matter of the blood, both possessing certain common derivatives.

Selective Action of Radiant Energy.—Returning to the artificial forms of radioactivity recently discovered, it may be stated that these, like sunlight, but in more powerful degree and probably in a different fashion—for sunlight has little or no X-ray activity—kill the germs of disease, as, indeed, they do all forms of living cell when exposed to them in sufficient intensity for a sufficient time. Fortunately for the treatment of disease by these forms of radioactivity, there is a certain amount of selective action in this activity upon different forms of living matter, just as there is in the case of the therapeutic action of drugs, and it is upon the difference in degree of activity that successful treatment depends.

This selective action varies with the type of ray employed, and the problem of practical radiotherapy is to discover which type of ray suits different forms of disease. There is now, for example, almost a consensus of opinion that lupus is best treated by the Finsen light, while rodent ulcer is more amenable to the influence of the X-rays. The results obtained by the use of the Finsen light in that most disfiguring of complaints and most intractable to ordinary therapeutics, viz. lupus, are most remarkable, and the Finsen lamp has now become a part of the armament of every specialist in diseases of the skin. The patient application of the Finsen light has this advantage over the older

and more drastic surgical remedies that it does not lead to still further disfigurement when the lupus growths, as is so frequently the case, lie on the face, and the results obtained appear to be quite permanent when sufficient treatment is given, the tubercle bacilli apparently being killed *in situ* in the tissues.

CHAPTER VIII

TROPICAL DISEASES

An important department of medical science in which important advances have been made in recent years is that of the diseases of tropical climates. Amongst the causative agents in the production of tropical diseases, it has been shown that animal parasites belonging to the protozoa play a larger part than the bacteria of vegetable origin which take a similar part in the etiology of the diseases of temperate climates.

The progress of work upon tropical diseases has shed, however, a reflected light upon the hitherto better known and more fully studied diseases of our own climate. An experimental review of the etiology of many of our acute infective diseases of at present unknown origin from the standpoint of protozoology would be of high interest, and might lead to a great advance in our knowledge of these obscure affections.

MALARIA.—The most important of the diseases which have hitherto been traced to protozoan parasites is malaria or ague, because of the large number of persons living near marshy districts in warm climates which it attacks, and the resulting lowering in vitality of large sections of the white population which it brings about, so conferring diminished resistance to other diseases, in addition to the enormous death roll directly due to the malaria itself. In ancient days malaria was one of the most prominent diseases amidst the Romans, and it is still the scourge of modern Italy; hundreds of thousands of the inhabitants of the United States of America are afflicted by it; it has earned for West Africa the appellation of "the white man's grave"; and thousands of the natives of India die annually directly from its ravages.

From early times it was known to be associated with marshy grounds, and it was supposed for centuries to be associated with miasmata or stagnant vapours arising from the marshes. But it has remained for the scientific work of the experimental medicine of the immediate past generation to clear up this riddle of the ages as to the true origin and nature of malarial fever.

The most remarkable symptom about malarial fever is the occurrence in ordered sequence of intermittent attacks separated by intervals during which the patient is fairly well. According as these attacks succeed each other at intervals of the third or fourth day the fever is described as tertian

or quartan ague, and there are less frequent forms with attacks every day (quotidian fever), or it may be that there are clear intervals of four, five, or even six days. Each attack, when it arrives, is of a similar character, there being a cold stage, a hot stage, and a stage of violent perspiration and relief. There is no drop of body temperature in the cold stage, but rather a rise, yet the patient feels excessively cold; the teeth chatter, and he shivers violently; the skin is shrivelled and the face and hands blue; there are violent pains in the back and limbs. The cold stage lasts from half an hour to two or three hours and is succeeded by the hot stage, in which the face becomes flushed though still dry; the patient feels burning hot and restless; there is excessive headache, and it may be delirium. After a variable period, from one to four or five hours, this is succeeded by the sweating stage, in which the temperature falls, and the patient loses the severe pains and feels more comfortable, but tired and inclined to sleep; during this stage there is copious perspiration all over the body, and pulse and respiration diminish in frequency.

The above sequence of events is repeated at regular intervals, varying in different cases as above mentioned.

The first important step towards the rational explanation of this peculiar symptom complex was made by the Italian observer Laveran, who demonstrated that malaria was always accompanied by the presence of a living organism in the red blood corpuscles of the patient. The appearances of the affected red blood corpuscles in malaria are depicted in the Plate DISEASE ORGANISMS.

The earliest stage in the evolution of the parasite is a ring form somewhat resembling a signet ring, shown by a corpuscle near the upper part of the figure, and by another corpuscle lower down in a slightly later stage of development; a subsequent stage is shown by two corpuscles somewhat lower in the preparation, and these finally form rounded spores in considerable number, as shown in a corpuscle in the upper left-hand corner, and in one near the bottom. As a last stage these spores disrupt the corpuscle and are set free at the same time, poisoning the blood and the tissue-cells with toxins, and precipitating the attack of ague when a large number are set free at the same time in the blood. Then the round is repeated, fresh blood corpuscles are attacked by the free spores, and when the corpuscles are again loaded with the next generation of spores there is another disruptive storm and a succeeding attack of ague. Hence the intermittent attacks of the malaria, in cases not treated by quinine, is due to a *synchronism* in the growth and development of parasites, leading to a simultaneous breakdown of many corpuscles and setting free of myriads of spores.

The remaining part of the puzzle was how the blood became originally affected by the malarial parasite, and what was the connection with the marshes. This portion of the history has been supplied in quite recent years by the brilliant suggestion of Patrick Manson, followed up by the patient work and accurate proof of Ronald Ross. These observers showed that this sporulating cycle occurring in the red blood corpuscle

did not form the complete life cycle of the malarial parasite, but had to be refreshed and supplemented at intervals in the manner described already as necessary after a certain number of generations in so many protozoa.

This other cycle was shown to occur in the stomachs of a certain number of species of a particular genus of mosquito known as the *Anopheles*. A particular species of mosquito of this genus was examined carefully by Ross at different periods, and the mosquito was found to develop a special cycle of the malarial parasite in glands of the stomach.

It was shown that a mosquito, a certain time after biting a patient, became infective, and was capable now of carrying malarial fever to another human being, but only after the parasite had gone through certain preliminary stages of development within the body of the mosquito. The practical advantages of these discoveries to mankind have been enormous in showing how the prevalence of malaria in communities is to be combated, and they have already saved many thousands of lives.

PREVENTION OF MALARIA.—In no instance where the difficult problems of thorough drainage have been solved, or removal of dwellings from the vicinity of mosquito-rearing swamps has been effected, has there failed of reaping the due reward in decrease of malaria and deaths from malarial fever, and in some instances districts which were previously decimated are now practically free from the scourge.

The problem of practical sanitation of a district against malaria is rendered somewhat easier by the fact that the parasite-bearing anopheles mosquitoes do not fly far from the shallow pools in which they deposit their larvæ, so that they may be swarming in a particular spot, and another district a few hundred yards or a quarter of a mile away may be quite free from them. A second factor of assistance is that their larvæ, in order to develop further, must at a certain period ascend to the air at the surface of the water, and hence by sprinkling on the pools petroleum oil, kerosene, or creosote, so as to form a thin layer on the surface, their development may be prevented. Hence the hygienic measures indicated are: drainage and disinfection by oil of all water within, say, a radius of one mile around a given town or community which it is desired to protect.

Some towns and situations are more ideally placed for such treatment than others, and in certain test cases, where communities were riddled with malaria, the disease has been practically stamped out by thorough carrying out of the measures indicated above. It may be added that, in Central America, the main obstacle to completion of the great undertaking of the Panama Canal was the health of the workmen, and that now malaria and yellow fever (carried by another species of mosquito, viz. *Stegomya*) have been almost crushed out by effective sanitation, and the work is being pushed forward to completion under healthy conditions.

SLEEPING SICKNESS.—Another important disease of tropical climates which has been conclusively shown to be due to a protozoan parasite, is the so-called "sleeping sickness", which in recent years has caused the death of hundreds of thousands of the native population of vast

districts of Central Africa, and has also killed a considerable number of white men. In certain districts the native population has been practically wiped out, and in many others the remaining population has fled in terror.

The disease is here also carried from individual to individual by an insect, the tsetse fly; but evidence is lacking that there is a cycle in the body of the fly, as in the case of malaria in the mosquito. The disease is one of a somewhat large class of diseases known as trypanosomiases, which are due to minute organisms called trypanosomes, found in millions in the blood. These protozoa were known for many years to cause disease in the lower animals, cattle, horses, and birds. Thus, one disease, called Surrah, or Indian cattle disease, is a veritable plague amongst cattle in India, causing a loss of over a million pounds annually. Another trypanosoma disease of African habitat, known as Nagana, or Tsetse-fly disease, borne also by the tsetse fly, is especially fatal to horses and oxen, and renders whole districts of the African continent untenable to white men by destroying all beasts of burden.

It is not many years ago since the first trypanosome was described in the blood of a European by Dalton, who fell a martyr to his work in Africa. Later, this organism was obtained in the cerebro-spinal fluid in sleeping sickness by Castellani, and shown by Bruce and his co-workers in the expedition to be the causative factor in all cases of sleeping sickness.

It is a common mistake to suppose that the victims of sleeping sickness are in a continuous condition of sleep. The somnolent condition is only developed at a late stage of the disease, and is not always the most prominent feature. It is true that a more or less somnolent condition does develop, but it can scarcely be described as sleep, and is more a profound cachexia, in which the mental faculties are involved, producing a kind of torpor. The earlier symptoms are swellings of the lymphatic glands and a progressive and very marked emaciation of the muscular system. A similar emaciation is seen in other types of trypanosomiasis in animals.

The question of the eradication of the disease by preventive measures is more difficult than that of malaria, first, because the fly belts are more widely spread, and secondly, because a native and less amenable population has to be dealt with. A large amount of patient study and laborious work has been devoted to the problem of discovering some drug which would act as a remedy in sleeping sickness, similarly to quinine in malaria, and a certain amount of success has attended these experiments, which in part have been carried out by bands of workers at home upon experimentally infected animals, and later tested on the large scale by expeditions in Africa. It is interesting to note that the pioneer in this quest was the great explorer Livingstone, who found that a certain amelioration and slower advance of the disease was effected by the use of arsenic as a drug.

Treatment of Sleeping Sickness.—After the discovery of the cause of sleeping sickness the question of treatment was taken up with a new impetus—amongst others by Thomas and Breinl at Liverpool; and these observers found that they obtained a certain amount of effect with

arsenic, but that it had to be given in almost poisonous doses, and even then was only very temporary in its effects. In a search amongst the organic compounds of arsenic for a drug which might have a less poisonous action upon the host and a more selective action upon the parasites, it happily occurred to them to try a new organic arsenical compound introduced in Germany for the treatment of cutaneous affection under the name of ATOXYL. This substance is a compound of aniline and arsenic acid (amidophenyl arsenic acid) which was first synthesized by a French chemist Béchamp over fifty years ago, but had lain neglected for many years until, as stated above, it was introduced in Germany under the trade name of atoxyl as a remedy in certain cutaneous affections in which arsenic is often prescribed. The tonic value of this compound for mammalia is only about one-twenty-fifth to one-thirtieth of that of inorganic arsenic, and, of highest importance here, its toxicity to trypanosomes is not so much reduced as is the toxicity to mammals. On trying this compound on experimentally infected animals it was found that by one or two administrations considerably short of the lethal dose the trypanosomes could be completely driven out of the blood even in heavily infected cases.

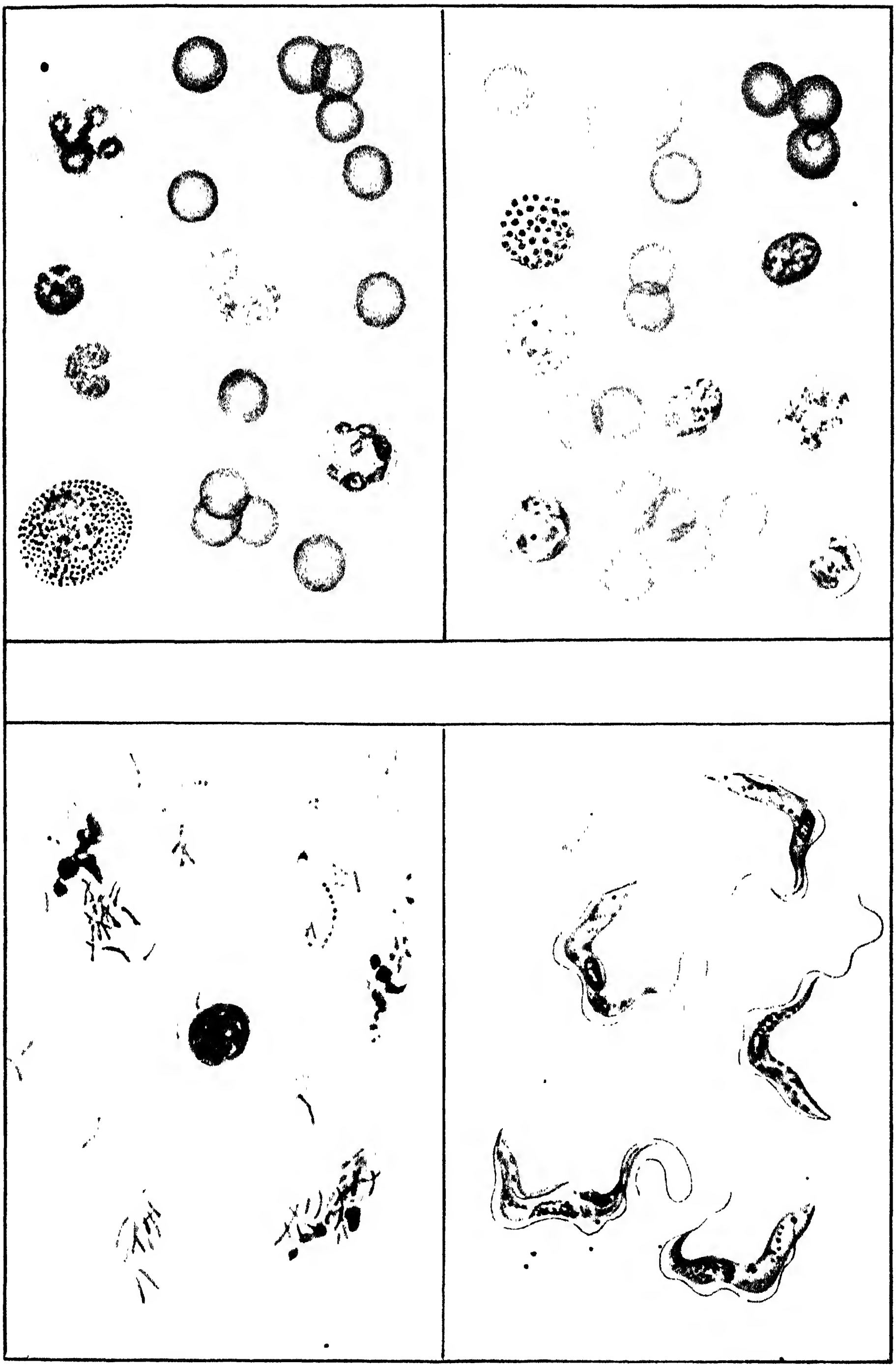
After the publication of these results, and also after a few trials had been made with considerable success in human cases by various observers abroad, the atoxyl treatment was carried out on a wholesale scale by Koch and his collaborators in an important German expedition in the Congo, which on its return reported very highly on the success of the treatment. Unfortunately in a large percentage of the cases there is a recurrence of the trypanosomes after a variable period; then they can be again driven out, and this may be several times repeated; but at each recurrence the parasites become less amenable to the influence of the drug, and finally quite resistant, so that they can no longer be ejected, and the case proceeds to a fatal issue, as, it may be remarked, it always does in a much shorter interval when left untreated.

It is known that in addition to the ordinary form of the trypanosome shown in the lower right-hand panel of the Plate, DISEASE ORGANISMS, there are latent forms into which it passes at a certain stage, and it was surmised that these forms might be those which remained latent in the host, and finally led to the recurrences on developing later into active trypanosomes. It was also considered probable that these latent forms might be amenable to some other drug than arsenic, and to test this hypothesis animals were given various other drugs after a preliminary driving out of the trypanosomes by atoxyl, and the period and percentage of recurrences noted. It was found that when a salt of mercury was used after atoxyl, in experimental animals, a much lower percentage of recurrences was obtained than with atoxyl alone. Thus atoxyl drives out the active stage and the mercury salt attacks and kills the latent stage, though it has no action on the active form usually present in the blood.

A great difficulty is the passage from results in small animals, such as rats, which are generally used in laboratory work, to large animals, such as oxen, horses, and men, for a very interesting though practically perplexing

DISEASE ORGANISMS FOUND IN THE BLOOD OR ORGANS OF MAN AND HIGHER ANIMALS

The top left-hand panel shows normal white and red blood corpuscles; on the right are shown malarial organisms affecting the red corpuscles. The lower figures show, on the left, tubercle bacilli (stained) from sputa, and, on the right, the trypanosomes which cause sleeping sickness in man and various tropical diseases of animals.



DISEASE ORGANISMS FOUND IN THE BLOOD OR ORGANS OF MAN AND HIGHER ANIMALS

reason. The effect of any drug upon the trypanosomes, which are small unicellular animals, is directly proportional to the concentration of the drug in the circulating blood, and hence to the weight of drug administered per unit of body weight of the host; but the effect of the drug as a toxic agent upon the complex host, in the case of arsenic, is chiefly as an irritant upon the intestinal area, and hence is proportional to surface and not to body weight. Accordingly the dose cannot be raised proportionately to the two body weights, but only in the ratio of the two-thirds powers of these weights. Hence if the body weight of a rat be to that of a man, as, say, 1 : 1000, the relative doses of an arsenical compound for rat and man respectively can only be as 1 : 100.

This theory is verified by direct experiment, and hence the concentration of the drug in the larger animal cannot be raised as high as in the smaller, and it is correspondingly less amenable to treatment.

In spite of these practical difficulties advance is being made in the study of this African scourge, and the goal will ultimately be reached. Quite recently a salt of antimony, viz. sodium antimonyl tartrate, has been shown by Plimmer and Thomson to have even a stronger specific effect in less doses than atoxyl, and it may be possible to give sufficiently large doses of this new remedy to prevent recurrences.

In the lower part of the Plate, DESTRUCTION OF MICRO-ORGANISMS, there are shown also illustrations of spirochætes, which are another form of protozoan, responsible for the production of certain relapsing fevers; no drug specifically active to these has yet been discovered.

CHAPTER IX

PUBLIC HEALTH

In the preceding pages some attempt has been made to illustrate in a general fashion the scientific methods by which the causes and treatment of disease are being studied in modern times. We may now in a concluding section give some account of the manner in which recent advances have improved the general health of the community.

LOWERING OF DEATH RATE.—Before passing to particular diseases, it may be pointed out that in many cases where our knowledge of the treatment or eradication of a disease falls far short of the point at which we can either radically cure the affected individual or stamp it out of the community, increased knowledge and its application in rational treatment for the individual, and hygiene for the nation, have led to more prolonged life for the individual and a higher percentage of recoveries and to a lower death rate. This fact is shown conspicuously in the case of many of the acute infectious diseases, where we can no more cut short the course of the disease by a single day than we could a generation ago, and yet both the percentage of deaths among those contracting the disease and the con-

tributions to the general death rate from the disease have been enormously reduced, both from our greater knowledge of how to nurse and guard the patient, how to prevent complications during the disease, and guard against possible sequelæ, and from the general advance in hygiene and preventive medicine causing diminution in the incidence of the disease.

Again, in more chronic infections, such as phthisis, the discovery of the rational cause of the disease in the tubercle bacillus, and the knowledge of how this is spread and propagated, have led us to precautionary measures which are largely responsible for the very large drop in the deaths from this disease.

ERADICATION OF DISEASE.—That certain diseases of known causation can be totally eradicated by vigorous preventive measures has been clearly demonstrated by the entire stamping out of hydrophobia in this country which has followed the stringent muzzling and importation measures for dogs which were introduced and maintained by Mr. Walter Long. No case of rabies has been known throughout the length and breadth of our land since the effective carrying out of this preventive measure, and now the dogs are free from the restraint of the muzzle; the people are free from hydrophobia and its horrors; and the dogs themselves from the risk of being often causelessly hunted to death by a frenzied mob terrified of hydrophobia. Unstinted praise is due to the statesman who stood firm and stolid through the necessarily trying period when humane persons and lovers of animals rabidly abused him in every newspaper in the country for supposed cruelty to their pets. The result justified the experiment, which suggests other attempts of a similar character with other infectious diseases.

LEGISLATION FOR PHTHISIS.—If there were someone bold enough and strong enough to insist on the segregation of consumptives for a period of five years, entirely apart from the remainder of the community; if importation of consumptives were entirely stopped; and if the greatest vigilance were exercised over early detection and separation, then, although at the end of the period of five years consumption might not be completely eradicated, the drop in its death rate would be enormous, and there would be a general verdict that the money and labour expended in the experiment had been amply justified by the result in useful lives saved to the community, and there would be no doubt of the vigilance being continued.

REPORTS OF REGISTRAR-GENERAL.—The recently published Decennial Report of the Registrar-General of Births, Deaths, and Marriages[1] supplies most interesting information as to variations in birth and death rates, and in the death rates at various periods of life and from various causes during the past fifty years or thereabouts. The curves here reproduced from this voluminous report show very graphically the variations in general death rate from all causes and also in some important diseases. A general comparison in figures of the important diseases showing increases and diminutions in the two decennia, 1881–90 and 1891–1900, is given in the accompanying table.

[1] Bluebook: *Supplement to the Sixty-Fifth Annual Report of the Registrar-General of Births, Deaths, and Marriages in England and Wales*, 1891–1900. Published, June, 1907. Price, 4*s*. 3*d*.

ANNUAL DEATHS PER MILLION PERSONS LIVING OF BOTH SEXES

Causes of Death.	1881-90.[1]	1891-1900.	Difference in 1891-1900. Annual Decrease.	Annual Increase.
Smallpox ...	44	13	31	—
Measles ...	406	414	—	8
Scarlet Fever ...	312	158	154	
Influenza ...	20	361	—	341
Whooping Cough ...	414	377	37	
Diphtheria ...	153	263	—	110
Croup (not membranous) ...	133	51	82	—
Enteric Fever ...	198	174	24	—
Diarrhœal Diseases ...	631	738	—	107
Puerperal Fever and Childbirth ...	161	152	9	—
Pneumonia ...	1,041	1,227		186
Tuberculosis (all forms) ...	2,429	2,010	419	—
Phthisis ...	1,775	1,391	384	—
Tuberculous Meningitis ...	234	216	18	—
Tuberculous Peritonitis, Tabes Mesenterica	257	217	40	—
Tuberculous Diseases (other forms) ...	163	186	—	23
Rheumatic Fever, *Rheumatism of Heart* ...	94	85	9	—
Cancer ...	602	758	—	156
Diabetes Mellitus ...	58	75	—	17
Laryngitis ...	52	45	7	—
Bronchitis ...	2,081	1,811	270	—
Pleurisy ...	56	54	2	—
Bright's Disease ...	286	337	—	51
Other causes ...	9,563	9,091	472	—
All causes ...	18,734	18,194	1516	976
Net decrease ...	—	—	540	—

The curve showing death rate from all causes commences with a value of 21.7 per 1000 in 1838, and shows only 15.2 per 1000 in 1905. There are many and very complex factors at work which make it exceedingly difficult to estimate in how far the reduction in death rate during this period of nearly seventy years is due to increased sanitary knowledge, and in how far it is due to other conditions.

In the first place, death rates cannot be estimated by percentages, since it is obvious that there is a minimum below which the rate cannot fall under the best possible conditions, and hence the two figures 21.7 in 1838 and 15.2 in 1905 mean more than their simple direct ratio. Again, the population of the country has considerably changed during this period from a rural to an urban population, as a result of which, acting alone, the death rate would have gone up if increased knowledge and sanitary law had not

[1] The death rates for 1881-90 are based on the sex and age constitution of the mean population of England and Wales in 1891-1900.

acted counter to the increased urban life. On the other hand, the birth rate has steadily diminished throughout the period; and, since the first years of life are most fatal, especially in urban districts, as a result the relative numbers of the population living at various ages have increased at the more healthy ages, so that this acting alone would tend to decrease the death rate. Taking all varying factors into account in a general way, the result of a decrease from 21.7 per 1000 to 15.2 per 1000 may be regarded as highly satisfactory, and a great tribute to the sanitary work of the period and our advance in general medical knowledge.

Even a casual glance at a table of general mortality (see table) is sufficient to demonstrate that the respiratory system is the most vulnerable portion of our frame, and that bronchitis in various forms, pneumonia,

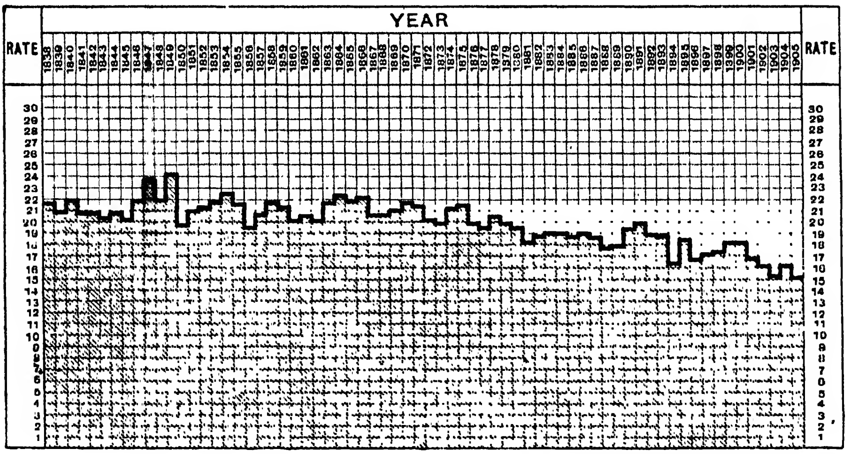


Fig. 437.—Curve showing Death Rate from all Causes, 1838–1905. The curve shows the annual death rate per thousand persons living at all ages.

and phthisis are amongst the most frequent causes of death. Thus that most dreaded of diseases, cancer, is only responsible for less than half as many deaths as bronchitis or tuberculosis, which are returned in nearly equal numbers.

Pulmonary Tuberculosis.—It is hence of especial interest to note that pulmonary tuberculosis is steadily decreasing amongst us (see fig. 438). One of the first observers to point out clearly this important fact, to chart out results for many years, and to show the relationship to improved sanitary conditions was Dr. Arthur Ransome, F.R.S., in the Weber-Parkes Essay for 1897. In the curve here shown these results are continued down to 1905.

Dr. Ransome points out that the decline in the incidence of tubercle of the lung cannot be ascribed to any special measure of repression, but coincides in point of time with the introduction of measures of sanitary reform, and with the improvements in the general conditions of life during the period, and adds: "It is imperative that all sanitary authorities should put in force the manifold powers which they now possess for improving

the public health, not only that they should attend to the sewerage and house and subsoil drainage, but that they should turn their attention to the still more important question of removing from their streets and dwellings, and places of public assembly, the more subtle and dangerous 'air sewage'.

"It is important that all insanitary property should be destroyed or made fit for healthy habitation; and that back-to-back houses, undrained and unaerated basement dwellings, should be done away with; that workshops and factories should be efficiently ventilated; that schools and places of public assembly should be more fully supplied with a flow of air adequate to the needs of their temporary inmates.

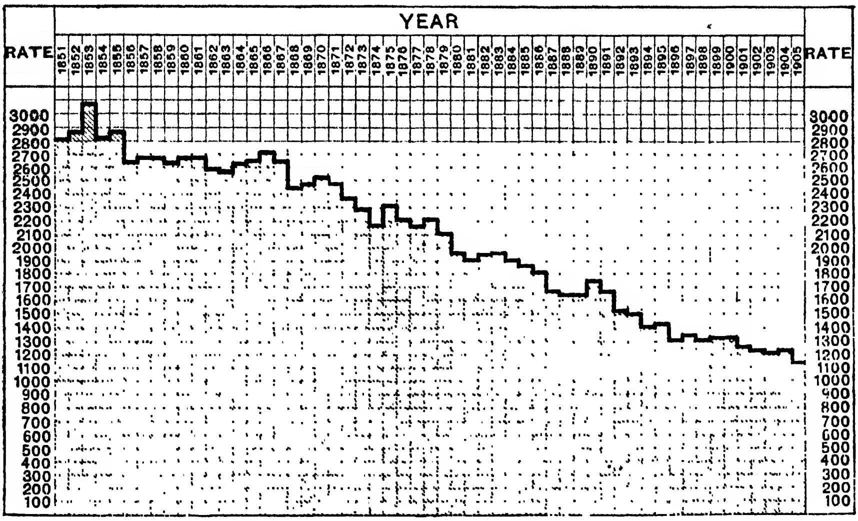


Fig. 438.—Curve showing the Death Rate from Phthisis, 1851–1905. The curve shows the annual death rate per million persons living at all ages.

"The outer air must therefore be kept as pure as possible; in the streets free course must be given to the wind; there must be no blind alleys or streets closed at one end; the width of streets must be proportional to the height of buildings, and an adequate space must be left around each building.

"Local authorities will therefore have to put in force their strongest powers for the prevention of pollution of the air; they must supply ample lung space in the shape of public parks and open playgrounds.

"When all this is done we cannot doubt that the great shrinkage in the mass of tubercular disease will continue to go on.

"When all our forces are brought fully into action we may surely expect that at least as great a rate of decline will be continued; and in this case another thirty years should see its vanishing point.

"We can hardly doubt that the retreat will go on at an increasing speed. When all health authorities perform efficiently the several tasks which have now been set before them; when, by the means which have

been mentioned, tuberculous cattle have been abolished from our herds; when the general public have been fully instructed how to deal with tuberculous material; and when, by means of open-air sanitoria in connection with all our great towns, the existing consumptives and other tuberculous patients are provided with the requisite essentials for their cure, then may we hope for complete success."

CANCER.—The statistics in the case of cancer show a complete converse to the more hopeful figures in the case of tuberculosis, since they prove that, in spite of the amount of attention and patient work that this disease has attracted in recent years, it is steadily increasing from year to year. Part of the increase may no doubt be attributed to more accurate diagnosis in recent years, and to more frequent exploratory

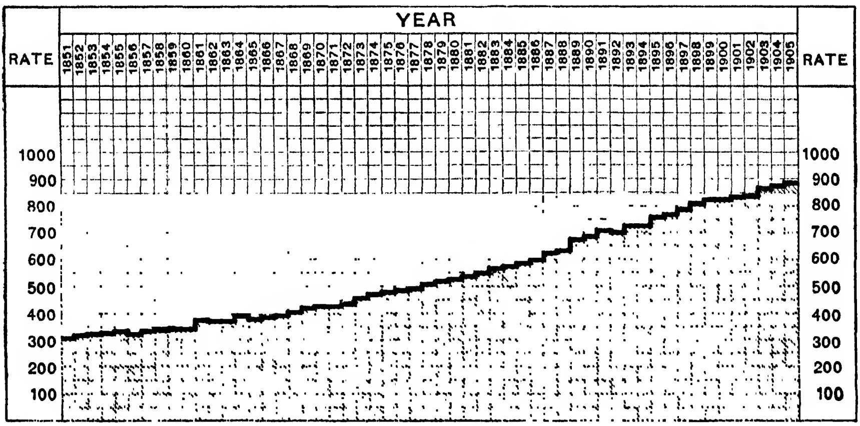


Fig. 439.—Curve showing Death Rate from Cancer, 1851–1905. The curve shows the annual death rate per million persons living at all ages.

abdominal operation, but, making all possible discount for such additions to the Registrar-General's statistics, there is little doubt as to a real increase in the ravages of this dread disease. The tide of patient research which is being poured upon the subject must in the end have its effect; the results obtained, even when of an entirely negative character, are gradually narrowing the ground of enquiry, and there are indications, some of which have been previously given, that we are gradually approaching a knowledge of the cause of the malady.

ENTERIC FEVER AND SMALLPOX.—The curve given in the case of enteric fever is but a typical example of the decrease in death rate in most of the fevers of infectious origin. Smallpox has almost ceased to be recognizable in our midst by the ravages it inflicts on the visages of its victims, although a generation ago it was obvious everywhere, and less than a century ago it played its pranks in the Courts of kings, and haled royalty itself to its last account.

SCARLET FEVER.—The diminution in fatality in scarlet fever is even more striking than in the case of typhoid fever, although this is more due to a less malignant form of the disease than to a greatly lessened

incidence. Diphtheria alone of these infectious febrile diseases shows a slightly increased mortality in spite of the antitoxic treatment previously described, but this is mainly to be attributed to a more perfect diagnosis

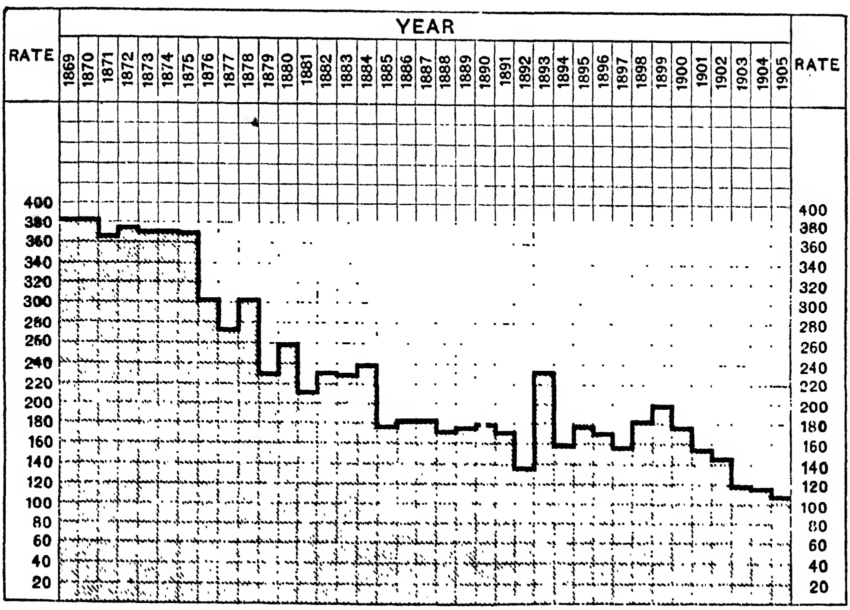


Fig 440.—Curve showing Death Rate from Enteric Fever, 1869–1905. The curve shows the annual death rate per million persons living at all ages.

and to the registration as diphtheria of cases formerly described as membranous croup, &c.

Taken as a whole, these records of public health administration during the past fifty years form an ample demonstration of the fact that, in spite of adverse conditions of city life and the strain of modern civilization, we live on the whole healthier and longer lives than our forefathers.

LIST OF WORKS RECOMMENDED FOR FURTHER STUDY

Name.	Author.	Publisher.
Essentials of Histology	E. A. Schäfer	Longmans, Green, & Co.
Haliburton's Handbook of Physiology	W. W. Haliburton ...	John Murray.
Elementary Anatomy and Physiology	Benjamin Moore ...	Longmans, Green, & Co.
A Primer of Physiology	Alex. Hill	J. M. Dent & Co.
Elementary Physiology...	Principal Ainsworth Davis	Blackie & Son, Ltd.
Practical Physiological Chemistry	Mulroy...	William Green & Sons.
Bunge's Physiological and Pathological Chemistry	Translated by Wooldridge	Kegan Paul, Trench, Trübner, & Co.
Principles of Medicine ...	W. Osler	Appleton & Co.
An Introduction to the Science of Radio-Activity	C. W. Raffety	Longmans, Green, & Co.
The Röntgen Rays in Medical Work	D. Walsh	Baillière, Tindall, & Cox.
Immune Sera	C. F. Boldwan... ...	Chapman & Hall.
Studies on Immunity ...	Robert Muir	Hodder & Stoughton.
A Manual of Bacteriology	R. T. Hewlett... ...	J. & A. Churchill.
Manual of Bacteriology	Muir & Ritchie ...	Young J. Pentland.
The Household Physician, 2 Vols.	Dr. M'Gregor-Robertson	Gresham Publishing Company.

ANTHROPOLOGY

BY

H. SPENCER HARRISON, D.Sc., A.R.C.Sc.

ANTHROPOLOGY

CHAPTER I

OUTLOOK OF ANTHROPOLOGY—ORIGIN OF MAN

OUTLOOK OF ANTHROPOLOGY.—Anthropology, or the Science of Man, deals with the story of the human race from the time of its origin until the present day. The branches of study involved in such a comprehensive subject are numerous, and some limitation is both necessary and desirable. Sciences such as physiology, psychology, and history, although they deal with man or his activities, are not regarded as branches of anthropology proper. Even when these special subjects are excluded, the outlook of the science is a vast one, since it embraces such questions as the origin and antiquity of man; his physical structure as shown in existing and extinct races and peoples; his grades of culture and their inception; the origin and development of his arts and crafts, and of the implements used in these and other activities; his languages and writing systems; and many other subjects dealing with his physical, material, mental, moral, and social evolution.

Throughout the whole science and its subdivisions the leading method is the comparative one, which has long been recognized as the most fruitful in results. The present condition of the races and peoples of the world can only be truly interpreted in the light of their past, which must be studied by reference to such historical, traditional, and archæological data as are available. A complete knowledge would enable us to trace back in detail the development of all modern peoples, physically and culturally, to the common stock from which mankind is believed to have sprung. Although it may be said with certainty that no such knowledge will ever be attained, it is the aim of anthropology to collect and correlate the information derived from a great variety of sources, and thus to render the whole story of man as complete and coherent as possible.

It is not necessary to define here the scope of such fundamental branches of anthropology as physical anthropology, ethnology, archæology, and comparative technology. In the present sketch a selection will be made from all these branches of those facts and theories which are either of especial importance from the evolutionary standpoint, or which are of such general interest that they cannot well be omitted.

Such complex subjects as the social organizations, the languages, and the superstitions and religions of mankind do not lend themselves to condensed exposition, and must be left for larger treatises.

ORIGIN OF MAN.—In his physical structure man is more nearly allied to the MAN-LIKE APES than to any other existing animals. The gorilla and the chimpanzee of equatorial Africa (fig. 441), the orang-utan and gibbons of the East Indian Archipelago, are the only modern representatives of this group, which was at one time more widely distributed in the Old World. Their structure is very similar to that of man, and it

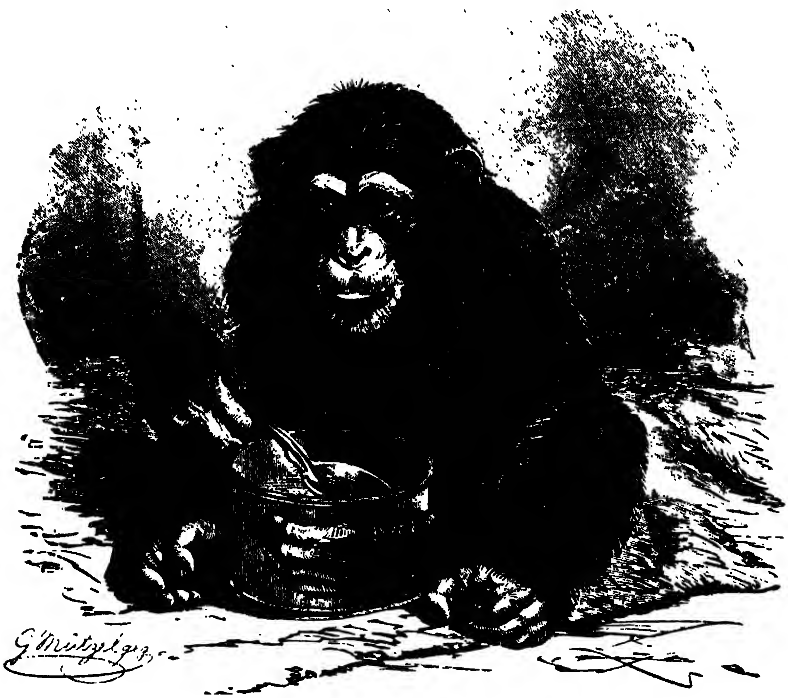


Fig. 441.—Young Chimpanzee (*Anthropopithecus niger*)

is believed that the human race is derived from an extinct animal not differing essentially from these apes. It is generally believed, also, that man arose in one region only, though the view has often been put forward that the main races of men had independent origins from closely allied but distinct ape-like ancestors.

Where the CRADLE OF MANKIND was situated cannot be determined with any degree of certainty, but there are several facts which justify the conjecture that it was somewhere in the equatorial region of Africa or Asia, or even in a now vanished land which lies beneath the waters of the Indian Ocean. The man-like apes and also the negroes and negritoes (which are regarded as the lowest existing races of man) have their distribution on either side of this ocean; moreover, remains have recently been

found in Java which suggest that at a remote period men of extremely low type were living in the eastern part of the area. The skull and thigh-bone of the Javan *Pithecanthropus erectus*, as the type was named by its discoverer (Dubois), indicate that the individual was less human in structure than any existing race of men. There is, indeed, much divergence of opinion as to the real nature of the remains; some anthropologists attribute them to a man-like ape higher in type than existing apes, whilst others are convinced that they are those of an ape-like man. Under the circumstances it is perhaps justifiable to regard them as belonging to a no longer missing link. Many others yet remain to be found.

Before man began to spread from his place of origin it is probable that he had advanced beyond the condition of his ancestors in the greater development of his faculty of memory, of his reasoning powers, and in the possession of at least the rudiments of the power of articulate speech. He had probably assumed the erect or a semi-erect posture, and had begun to make and use simple tools and weapons. These early advances contained the promise of man's dominance upon the earth, which is based upon special characters of body as well as of mind.

The BRAIN, though structurally a portion of the body, plays an altogether unique rôle in determining the status of the individual, and its high development has been an essential factor in the progress of the race. In proportion to size of body, the brain of man is much larger than that of any other allied animal, and although we cannot say that mental power is to be measured by bulk of brain, there is certainly a relation between the two. It is, however, in quality of brain rather than quantity that man differs from the lower animals, and the difference is immeasurable, although of natural growth. From his power of storing up past experiences in his mind, and of making use of them under the guidance of his intelligence and his reason, man derives an adaptability which far transcends in utility the instincts of animals.

In his power of SPEECH, again, which is a combined function of the brain and the organ of voice, man has an overwhelming advantage, since the individual can communicate definite ideas and facts to his contemporaries, and the knowledge so acquired can be transmitted from one generation to another. The power of speech has, moreover, aided greatly in the general development of the mental faculties.

In spite of the great difference between the MIND of man and that of all other animals, there are no facts that need induce us to regard him as an intruder and an alien in the animal kingdom. The fundamental resemblances are too close to permit of the assumption that the process of evolution, by which the present diversity of organisms has arisen, was inadequate to modify and transform both mind and matter.

In the evolution of man the STRUCTURE OF THE HAND has played a most important part. The hand of existing apes and monkeys is essentially similar, and so also no doubt was that of man's ape-like ancestors. It was probably the combination of a superior degree of intelligence with the manipulative power of the hand that led some group of the higher apes into the path of progress upon which

we still advance. By its power of grasping, weighing, and otherwise testing the properties of objects, the hand was of inestimable service to early man, as it is to us. The first men inherited from the brute the power of handling or wielding fruits, stones, and the boughs of trees, in a manner only possible to an animal possessing a hand that could grasp, and a thumb that could be opposed to the fingers. The information obtained by the use of the hands, and the progress made in the skilled employment of them, served to exercise and develop the brain. Upon the earliest attempts to make use of stones and sticks as tools and weapons were based the later advances in the production of artificially shaped implements. Man is sometimes described as A TOOL-MAKING ANIMAL, and in this definition we have an epitome of the causes of his success. But it is not by the hand alone, or by the brain alone, that he has made his way; the two organs have developed as the result of constant interaction and close co-operation.

As a feature in man's organization that has greatly influenced the development of his manual skill, much importance must be attached to his habitually ERECT POSTURE. The higher apes use their hands in climbing and to some extent in walking, whereas, by a complicated adjustment of other parts of the body, the hands of man have been entirely set free from all share in locomotion, and have therefore become at liberty to develop into more highly sensitive organs of touch and manipulation.

Finally, man's SOCIAL INSTINCTS and habits have not only given him the benefits of co-operation, but have also brought about that interchange of ideas which is so essential to all material as well as mental and moral progress.

CHAPTER II

ORIGINS OF INVENTIONS—TOOLS AND WEAPONS

Man has progressed through the ages to his present position of supremacy largely as the result of his power of utilizing the forces and products of nature for his own ends, and of accumulating and transmitting his knowledge by tradition or writing. From the simplest beginnings his artificial contrivances have become more effective and more differentiated, and, as will be seen, all improvement has been the result of the gradual modification of what had gone before. Although there are comparatively few of the implements of early man preserved to us, and none that can with any degree of probability be regarded as his first productions, it is often possible to give a plausible guess at the origin of the main types of tools and weapons. The study of the origin and evolution of the implements of prehistoric times is facilitated by the existence of modern races in low stages of culture, whose tools and

weapons are fashioned from wood, stones, and parts of animals, by processes often so simple that they might well have been practised in still simpler forms by primitive man many thousands of years ago. The STICKS and STONES used as tools and weapons may be said to be the first ancestors of a very great number of man's artificial appliances.

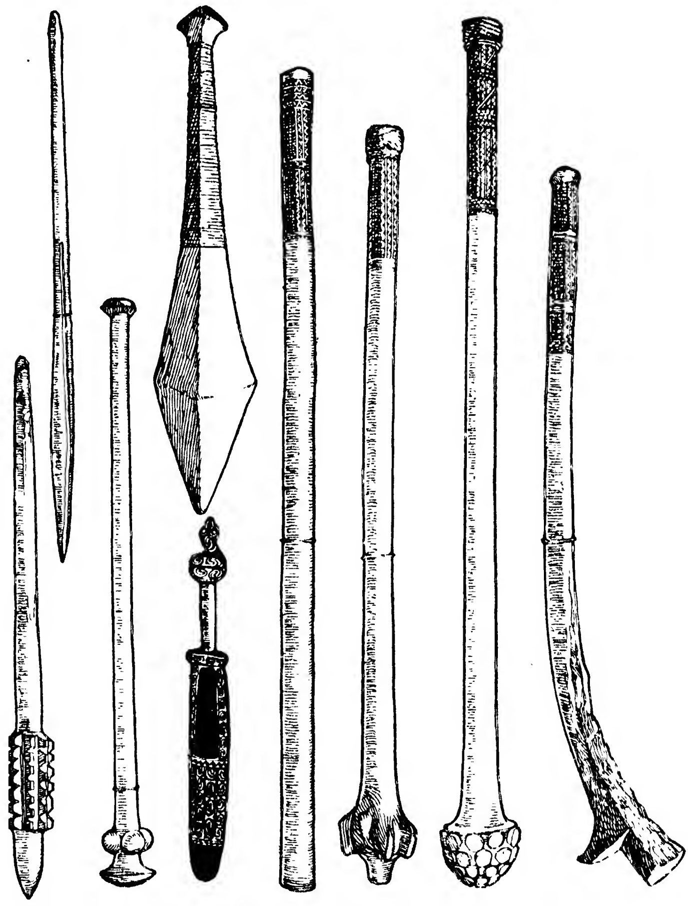


Fig 442.—Wooden Clubs from Australia, New Hebrides, Solomon Islands, New Guinea, Tonga Islands, Fiji Islands. Several are mace-like in form

Some existing apes are intelligent enough to use stones and fruits as missiles, and so also in all probability were man's non-human forefathers.

It was a considerable step in advance when early man discovered that the natural objects he found ready to his hand could be shaped and trimmed so as to make them more effective. The intentional cracking of a smooth stone in order to get a cutting or a chopping edge may have been man's first step from the tool user to the TOOL MAKER, and in all probability even this was the result of experience in the use of naturally fractured stones. Both stick and stone may have been

employed primarily as weapons, but the later developments of both forms were in numerous directions.

The CLUBS of modern savages, the war maces of mediæval Europe, the ceremonial maces of Parliaments and learned societies, have their origin in the heavy fighting-sticks of former times. An accidentally broken-off bough may well have been the earliest form of club, the beginning of a long line of descendants. Amongst modern uncivilized

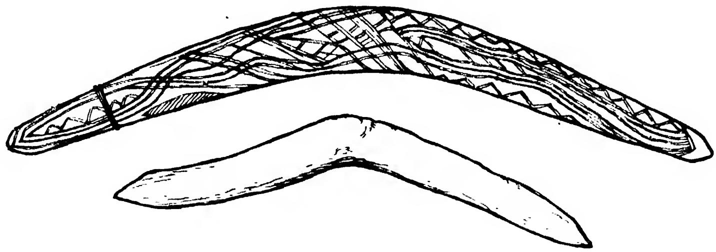


Fig. 443.—Australian Boomerangs

races, more especially in the islands of the Pacific, the club has been made in a great variety of forms (fig. 442). It is almost invariably well finished, and its shape is rarely plain and cylindrical. Knobbed and spiked ends are often found, whilst in some instances the form is that of a heavy paddle. In the Fiji Islands the trimmed and smoothed stem of a young tree is often used for a club, the roots at the base being left projecting for a short distance to form bosses or blunt spikes. In the neighbouring Tonga Islands the root-projections are imitated by carving away portions of the wood. Here we have a natural origin of a very common method of arming the head of a club, and it is probable that a similar mode of evolution of clubs of this type has occurred elsewhere.

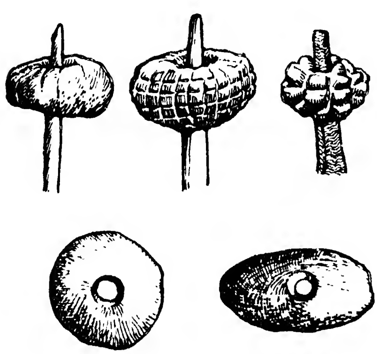


Fig. 444.—Stone Heads of Clubs or Maces, British New Guinea

Flat clubs, almost sword-like in form, are often met with, and in Australia the aborigines use a flat curved blade of wood, usually called the BOOMERANG, which is in some instances of such a form that when thrown it will return to the thrower. The boomerang no doubt had its origin in a flat curved missile-stick, and the accidental production of a curve of proper form led to the discovery that a certain shape of club would turn in the air after a long flight and come back to the thrower. The "come-back" boomerangs are in the main playthings, or sporting weapons, but non-returning forms are used in fighting.

Bone and stone are sometimes used as material for clubs, but only in rare instances. A plain straight shaft weighted with a heavy stone knob or disc is, however, a weapon still used in New Guinea (fig. 444).

and New Britain, and similar forms were formerly used in Europe and in some other parts of the world. These are in reality MACES, and we may see in them the origin of the metal-headed and all-metal maces of Europe and Asia, which again have given rise to the ceremonial maces referred to above. Side by side with such a specialized form of club as the mace of the House of Commons we may place the Irish shillelagh, which is a mere stick of hard wood, so primitive that it would be scorned by any of the inhabitants of the Oceanic Islands.

The naturally ROUNDED STONE has been, and to a less extent still is, very widely used both as a weapon and a tool. The stone thrown by hand was never an important weapon of war, though it has been used by many primitive peoples as a minor weapon. In the New Hebrides cylindrical missile stones, artificially trimmed and ground to the shape and size of a thick ruler, were used in battle. The SLING-STONE has had a very wide range in time and space, and whilst in many instances the nearest suitable stones were picked up from the ground, in others the missiles were artificially shaped, as in New Caledonia. The way in which the principle of the sling was first discovered is not known. Leaden bullets were sometimes thrown from the sling in early European warfare, and the bullets discharged by cannon and firearms in later times were essentially similar. With the further development of explosives the cannon ball was replaced by the shell, which may thus in a sense be said to be ultimately derived from the missile stone of the man or the ape.

As a tool the rounded stone has been widely serviceable in the working of stone by primitive races. Held in the hand, and used for battering and flaking, the flint or other HAMMER-STONE, with which so many of man's simple tools and weapons have been made, has been employed in all parts of the world at one time or another. Perforated or grooved for the attachment of a haft it became a hammer, and as such it is the prototype of our modern metal-headed hammers, whilst stone-headed clubs and maces of metal are also related in their origin to the hammer-stone. Indeed the very word "hammer" means a stone.

The innumerable types of SPEARS, JAVELINS, LANCES, HARPOONS, and ARROWS are derived from the sharp-pointed stake, which we may legitimately suppose to have been used as a weapon by early man. The Australian aborigines, whose appliances help us in so many ways to realize what may have been the first steps in invention, sometimes use a short stick pointed at both ends either for stabbing or for throwing. The spears of many of the islands of Oceania, such as New Guinea, are often merely long pointed poles of hard wood, sometimes hardened in the fire at the point. Such simple spears have had a widespread distribution in space and time. Barbs are frequently carved in the wood, or they may be in the form of separately attached splints of wood or bone. The points of the spears of modern savages are frequently of wood, but stone, bone, horn, and such natural objects as the spine of the sting-ray are also employed. The steel-pointed spears and lances of Europe and Asia are more directly derived from the stone-headed spears used

in prehistoric times, but before the dawn of history stone had given way to copper or bronze, and bronze to iron.

In various parts of the world it has been independently discovered that in spearing large fish, or other aquatic animals, it is often an advantage to attach the point loosely to the shaft, and connect the two by means of a cord. The shaft is less likely to be broken when this method is adopted, and it may also serve both as a drag upon the flight of the prey, and as a buoy to signal its whereabouts to the hunter. The Eskimo of the Arctic regions have invented various types of such harpoons and harpoon arrows, which illustrate in a striking manner the ingenuity developed under stress of the imperative necessity for efficient weapons of the chase. The "tozzle-head" harpoon of the European whaler was in part derived from that of the Eskimo.

The fish arrow, or spear with several points, is a weapon met with in practically all parts of the world. The trident associated with Neptune is such an appliance, and is evidence of the fish-spearing practised by the fishermen of classical times in the Mediterranean. The modern salmon leister is a similar weapon.

The spear is either held in the hand or used as a missile, and in several parts of the world an appliance has been invented for giving the arm additional leverage for the discharge. This is the THROW-STICK or SPEAR-THROWER, used in the Arctic regions, in tropical America, and in parts of the Pacific, especially Australia. It usually consists of a short stick with a peg at one end, which fits into a pit in the end of the spear. The use of this appliance provides the arm with an additional joint, and its action is essentially similar to that of a sling. The spear-thrower was in use in Europe in the Stone Age, before there is any certain indication that the bow had been invented. We may regard it as a predecessor of the latter weapon, which surpasses it so much in efficiency that only in a few parts of the world has the spear-thrower been able to hold its own, either because the bow is unknown (Australia), or because the spear-thrower is more convenient for special purposes (Eskimo). The principle of the spear-thrower differs so much from that of the bow that the one could not possibly have been derived from the other.

The BOW is a device for the discharging of small spears called ARROWS, which were no doubt derived from spears. They are therefore, by derivation, pointed sticks, and in a few instances they are still found in use in this form. Frequently, however, they are complicated in structure, and they are often provided with adaptations fitting them for accuracy of discharge and flight. Shaft, foreshaft, point, barbs, feathers, and nock-piece may each be independent elements fitted together by socketing, tieing, glueing, or by some other of the many methods that have been devised. Wood, bone, stone, metal, and other materials may furnish point and barbs, but the shaft is almost invariably of wood, usually lighter in weight than the foreshaft or point. The origin of the bow is not known, since its use dates back to a period long preceding the dawn of history. It is still an important weapon in many parts of the,

world. The earliest form was no doubt the plain, or SELF-BOW, consisting of one piece of wood (the stave), but many Asiatic and American bows are made up of a combination of wood, or bone, with sinew and other materials. It is probable that such COMPOSITE BOWS were first devised by a people living in a cold region, where suitable elastic wood was very scarce or unobtainable. They discovered that the addition of sinew, either in the form of a thick cord (as in the case of many Eskimo bows), or of thin layers attached to the stave (as in the case of most other forms of composite bows) would give the necessary spring to inelastic material, such as pinewood. Indian and Persian composite bows are very complex structures, built up of wood, horn, sinew, glue, bark, lacquer, and often other materials, but their origin must be traced back to the simpler bows of Northern Asia (where the type probably originated), in which the bowstave of stiff wood has a thin layer of sinew attached along the whole length of one face. The CROSSBOW is also derived from the plain bow, from which it chiefly differs in being fixed to a stock. This type has been extensively employed in war and hunting in Europe and Asia, but amongst uncivilized peoples in other regions it is only found in one or two parts of Asia and Africa; the African crossbow has lately been shown to be of European origin. In European countries the evolution of the bow (crossbow) came to an end when firearms proved their superiority, but in China a magazine crossbow was evolved, which was employed so recently as in the Chino-Japanese war of 1894–5.

For cutting, sawing, and chopping, primitive peoples in the present and in the past have devised a great number of appliances made of stone, bone, wood, shell, teeth, and other appropriate materials. In many of the Pacific islands pieces of bamboo, with the hard siliceous rind forming the cutting edge, are used for KNIVES in the dismembering of animals or human beings. In the same region we find, in several groups of islands, lacerating weapons made of sharks' teeth attached in rows along wooden shafts. It is, however, the stone tools and weapons that not only date back to a period of remote antiquity, but have been closely concerned in the origin of our modern cutting and chopping tools and weapons.

The first implement with an edge may have been a naturally broken stone used for hacking off the branch of a tree for use as a club, but, later, man discovered that he could manufacture more effective tools. In the first part of the European Stone Age definite CHOPPING TOOLS OF STONE were made, with a thick butt for holding in the hand. Smaller sizes of implements of the same type were also made, and were probably used for cutting. Simple flakes of flint were also no doubt employed as knives, and they may be paralleled in modern times by the stone-bladed knives of Australia and the Admiralty Islands.

In the later portion of the European Stone Age (the Neolithic or New Stone Age) we find that there is a marked distinction between knives and chopping implements. The latter were made of flint and other kinds of stone, and they were often finished by grinding and polishing. Whilst some of them may have been held in the hand during

use, others were evidently intended to be hafted, as are the similar implements still used by the natives of New Guinea and some other islands of the Pacific. The modern AXE and the ADZE originated in these polished stone implements, and we may follow the course of evolution of the type from stone to copper, from copper to bronze, and from bronze to iron (fig. 445). Whilst the stone adze was entirely a tool, the axe had also a place amongst the weapons of the warrior.

The best-formed knives of the Neolithic Age were leaf-shaped blades of flint, such as had already been made in the later part of the Palæolithic Age. In some cases they were no doubt provided with a grip of skin, like the modern stone knives of some North American Indians. With the discovery or adoption of metal in Europe it became possible to make knives and DAGGERS of greater efficiency. Later it was found that the

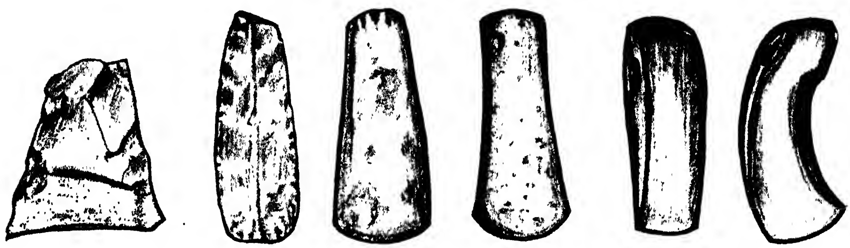


Fig. 445.—Series illustrating Evolution of Axe-head in Prehistoric Times

a, Kitchen-midden type, Denmark. *b*, Unpolished stone axe-head, England. *c*, Polished stone axe-head, Denmark. *d*, Flat copper axe-head, France. *e*, Perforated stone axe-head, Denmark. *f*, Perforated bronze axe-head, Hungary.

length could also be increased with advantage, and from the bronze dagger the SWORD was derived (fig. 446).

The BLOW-TUBE or BLOWPIPE, a weapon used for discharging small poisoned darts by means of the air forced from the lungs, is identical in principle with the peashooter. It is now found as a weapon in two parts of the world—in south-eastern Asia, and in the northern parts of South America. Its length may be as great as 14 ft., and in construction it ranges from a simple rod, bored throughout its length, to a double tube, one hollow cylinder inside another, or a tube made up of two grooved halves closely fitted together.

The BOLAS, of South America, consists of two or three heavy balls, encased in raw hide and attached to each other at a common centre by means of long thongs, and is used chiefly for capturing wild horses and ostriches. One of the balls is held in the hand and the other one or two are swung round the head at the end of their cords. When sufficient velocity has been attained, the apparatus is sent whirling through the air, and the prey is firmly entangled in the cords. A similar weapon, on a much smaller scale, is used by some Eskimo tribes.

The LASSO, a weapon consisting of a long cord with a noose at the end, has a long history, but it has been most extensively employed by the Indians of Spanish America. It was no doubt originally derived from

the NOOSE, which is used in many parts of the world for capturing birds and other animals.

FIREARMS belong to advanced stages of culture, and their construction and evolution cannot even be outlined in this brief sketch.

The numerous TRAPS, snares, decoys, and other devices for catching

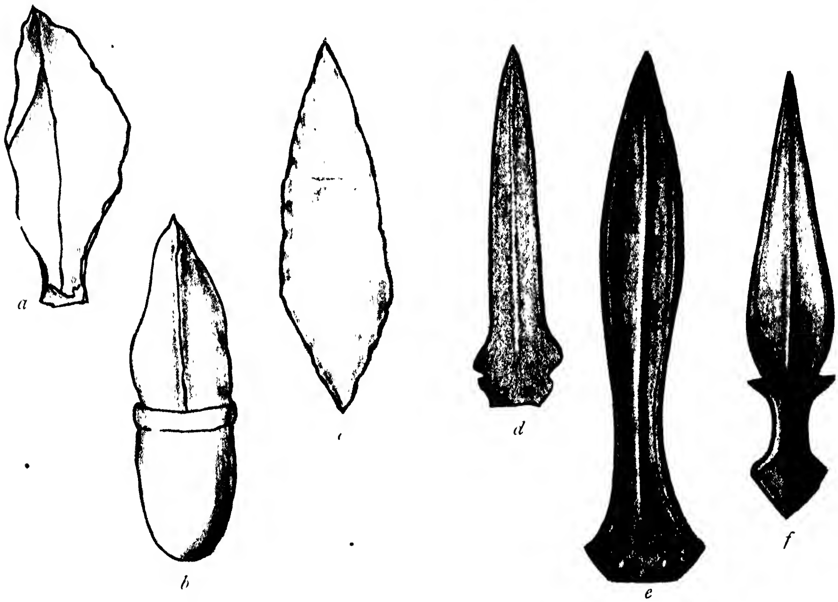


Fig. 446.—Series of Leaf-shaped Blades of Daggers, Spear-heads, &c.

a, Flint flake, Neolithic Age, Ireland. *b*, Australian stone knife, with handle of hard gum. *c*, Flint blade, Cave Period, France. *d* and *e*, Bronze dagger- and sword-blade, Bronze Age, Europe *f*, Iron-bladed dagger, Modern Africa.

animals provide us with a multitude of examples of the ingenuity of man, but they also must be left on one side.

Amongst defensive weapons the SHIELD is the most important, and its origin in many parts of the world is probably to be found in the use of clubs for parrying the oncoming spear or arrow. In Africa and

Fig. 447.—Narrow Shield or Parrying Stick, Australia

Australia very simple shields are found, consisting merely of a short bar of wood with a handhold in the back, and it is by the expansion of such types that many forms of shield have probably arisen (fig. 447).

BODY ARMOUR has not been very extensively used by primitive man, but in Europe and Asia there are many indications of the connection between the natural armour of animals, in the form of scales and plates, and the similarly constructed armour of the soldier.

CHAPTER III

ORIGINS OF INVENTIONS—(*Continued*)

The hunting and capture of animals are fundamental activities of man, necessary in many cases for his very existence, but fighting with his fellow man has always been as much of a luxury as a necessity. It is therefore not surprising that amongst the lower races, as amongst the higher, the inventive faculty has been directed with great intensity to the production of new and improved weapons of war and the chase. It is chiefly in other directions, however, that the origins of more advanced culture are to be sought.

DOMESTICATION OF ANIMALS.—When the HUNTER began to domesticate the more docile of the animals he killed for food, perhaps in some cases by bringing to his camp the young animals as pets for his children, he earned the gratitude of his posterity, who benefit by the companionship, the labour, or the food products of such animals as the dog, the horse, the ox, the camel, and many others. From the hunter to the HERDSMAN is also a step in advance, since the latter has a greater certainty of obtaining food, and is therefore more able to devote his attention to other means of promoting his material and other interests. Moreover, the responsibility of flocks and herds, the necessity for the exercise of foresight in protecting them from human and animal enemies, and the tending them in health and in sickness, exercised an elevating influence and led to an advance in culture.

AGRICULTURE.—It is, however, the agriculturist who must be regarded as the founder of civilizations. Agriculture, like all man's arts and crafts, may be traced to very simple and natural origins. The earliest forms of vegetable foods were those secured by the mere labour of plucking. Succulent fruits could often be obtained without difficulty, the shells of nuts might be cracked with the teeth or with a handy stone, whilst many edible roots or tubers could be grubbed up from the ground. Several modern races, such as the Andamanese, obtain much of their vegetable food by similar primitive methods. Agriculture on any considerable scale is dependent upon the growth of certain plants, which have been improved from wild varieties by constant selection. At first the cultivation of plants merely consisted in removing weeds and other obstacles to the free growth of selected varieties, but at a later stage they were transplanted and grown in prepared plots, or the seeds were collected and sown. When the native women of California beat out the grains of the naturally growing sand-grass into baskets, they practise a form of threshing, the preliminary steps of preparing the ground and sowing having been left to nature, whilst that of reaping is omitted altogether. Some Australian tribes obtain food from wild grasses in a similar way. The cultivation of cereals, such as wheat, maize, rice, and millet, which has played such an important part in the growth of civilization, in all probability had some such origin. Appliances for primitive agricultural operations are not only used by many modern

uncivilized races, but can be shown to date back to periods before history in civilized countries.

A simple POINTED STAKE FOR DIGGING up roots and tubers, and occasionally for turning over the soil in preparation for planting, is used by the natives of New Guinea and other Oceanic islands, by some American Indians, and in several other parts of the world (fig. 448). By the broadening of the stick to a paddle-like form the SPADE is foreshadowed, and a digging stick with a curve near the end is the prototype of the PICK. In New Caledonia a pick-like club is employed in war and in

Fig. 448.—*a*, Pointed wooden digging stick, such as is used in Australia, New Guinea, the Andaman Islands, and elsewhere. *b*, Digging stick with flattened end, South America.

agriculture, and within comparatively recent times a simple wooden pick was used in Sweden. By the widening of the point of the pick, or by the addition of a blade, or head, of stone or steel, the HOE was evolved.

With the discovery of the metals the hoe as we find it at the present day in Europe, Asia, and Africa, was produced, but probably before this occurred the implement had given rise to the early forms of a still more important appliance. This was the PLOUGH, which in several regions still suggests its origin as a hoe or pick, provided with a longer haft for the yoking of men or oxen, and a handle near the blade for the plough-

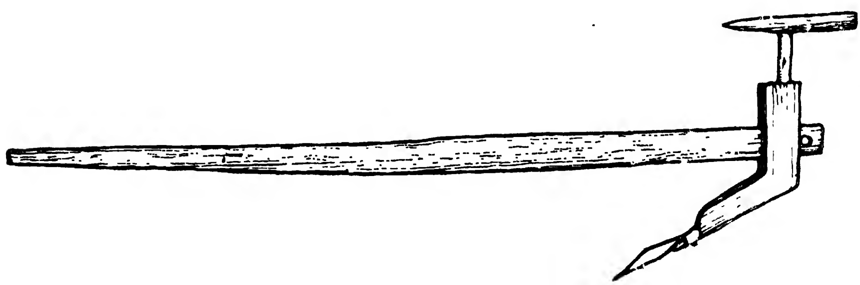


Fig. 449.—Diagram of Simple Type of Plough, such as is still used in parts of Europe and Asia

man. The ancient Egyptians figured most of their daily occupations on their numerous monuments, and in one of these is represented a man using a pick-like hoe, whilst near him is a ploughman driving a plough, drawn by two oxen, which is essentially a larger hoe with the addition of handles for the ploughman. From the pointed digging stick to the pick and hoe, and from these to the simple plough, with its later improvements for cutting into the soil, freeing it from underlying parts, and turning it over in a definite and regular manner, we have an uninterrupted line of evolution of invention which has led to the highest types of the modern plough.

The first reaping of corn, which was already grown in Europe before the age of metals began, and therefore long before history, was probably done with flint knives of crescentic form, such as have been found in various parts of Europe, Asia, and Egypt. SICKLES of copper or bronze succeeded those of stone, and were themselves displaced by iron implements differing in no essential respects from those generally used up to the middle of the last century in Europe, and still not quite obsolete. The SCYTHE is an improved form of sickle, and the modern REAPING MACHINE is merely an appliance for cutting down the corn with the least possible expenditure of labour and the greatest efficiency.

Fig. 450.—Girls Grinding Corn with Stone Grinder on Rock, near Lake Tanganyika, Africa. (By kind permission of Dr. W. A. Cunnington.)

The FLAIL for threshing is simply a stick with a joint, and the modern THRESHING MACHINE in its essential parts can do no more than apply the ancient principles of beating or rubbing the grain from the ear.

In the preparation of flour from wheat, maize, or other hard grain we have another striking example of the evolution of appliances from the simple to the complex, with identity of principle throughout. The North American Indian or African woman often grinds her corn between a fixed stone and another held in the hand (fig. 450); the same method was practised in Europe and in Egypt in the Stone Age, but it gave place later to the use of two large circular stones of similar size, the upper one rotating on the lower and being worked by hand. This is the QUERN, which is still used in North Africa, and has not completely disappeared from the remoter districts of Europe. The GRINDSTONES of the flour-mill constitute a large quern, no longer worked by hand, but with the upper stone rotating on a pivot connected with a wheel, which is moved by wind, or water, or steam power. The grinding of corn in modern mills is, however, now usually done between metal rollers.

FIRE-MAKING.—In association with the preparation of food we may briefly refer to methods of obtaining fire. The three principal modes are by wood friction, by percussion, and by chemical action. The two former appear to have been independently discovered in various parts

of the world, unless, indeed, they were already known to man before his dispersal. Man's first fires were probably obtained from natural conflagrations, and they perhaps served him mainly for keeping away nocturnal prowlers. At that time he was careful to preserve the fire when once obtained, and he no doubt carried it with him in his wanderings, as is still done by some Australian and American tribes, who are, however, well acquainted with methods of making it afresh. How he discovered that the friction of one piece of wood upon another—either by twirling (drilling one piece of wood into a pit in another) (fig. 451), or by rubbing, or by sawing—may be made to generate sufficient heat to ignite the wood dust produced, cannot be decided, but such methods have been, or are, used in practically all parts of the world. Amongst modern races the Andamanese are alone in their ignorance of any method of making fire, and they have therefore to keep their fires continually burning. Some races, such as the Eskimo, have ingenious methods of working the FIRE-DRILL by means of a bow or a strap. Accident may have led to the discovery that two pieces of iron pyrites, or iron pyrites and flint, will produce fire on concussion, and this method of obtaining fire appears to have been known long before the end of the Stone Age in Europe. By replacing the pyrites by iron or steel the FLINT AND STEEL came into existence, and it persisted in general use even in Europe until a few decades ago, and is still widely employed. The invention of chemical means of obtaining fire (MATCHES) rendered other methods superfluous, except where matches are expensive or unobtainable.

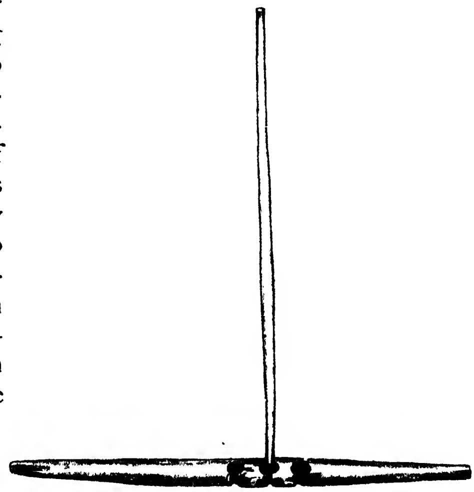


Fig. 451.—Two-stick Fire Drill, North America

The numerous methods of preserving fire and of using it for illuminating purposes cannot be considered, but we may note that such a primitive LAMP as that of the Eskimo, who burn a short piece of wick in oil contained in an open stone or clay dish, leads us through various improved methods in other regions to the best types of modern oil lamps.

POTTERY.—Nothing need be said concerning the use of natural vessels—of gourds, coconuts, ostrich-eggshells,—for holding liquids, but the development of artificial receptacles for food calls for brief notice. BASKETS are vessels which are made in some form or another by practically all races of man, and in some instances they are so skilfully constructed that they may be used for holding liquids. From our present standpoint, however, they are chiefly of interest from their probable association with the origin of pottery. Pottery-making was perhaps derived, in some parts of the world at least, from the use of clay plastered on the outside or inside of baskets,

to enable them to be used as cooking utensils or to render them water-tight. It is easy to realize how such a practice may have given rise to the production of independent clay vessels. The pottery of primitive people is shaped by hand alone, though the POTTER'S WHEEL is in some cases foreshadowed by the use of a movable stand, such as a stone, a piece of a broken pot, or a shallow basket dish, for holding the base of the pot that is being made.

The chief methods of giving to the clay the shape of the future pot are three in number. The clay may be simply modelled by the hand to the desired form (see Plate); or it may be moulded upon some other object, such as a basket or gourd, which is destroyed in the course of the firing of the pottery (this method appears to be now obsolete); or, lastly, the pot may be built up by coiling strips of clay one upon the other in the form of a continuous spiral, pressing the coils together as the work proceeds. With the invention of the potter's wheel, which was not known in Britain till shortly before the beginning of the historic period, the modelling method became the principal one used in the Old World.

Fig. 452.—Masai Women with Metal Ornaments, British East Africa. (By kind permission of Dr. W. A. Cunnington.)

CLOTHING. — The clothing of the body is not a matter that has given the majority of uncivilized races any great concern. In many instances the surface of the skin is regarded as a favourable situation for the painting or the TATTOOING of ornamental designs, which often have a totemic or tribal significance. The idea of clothing probably originated, at any rate in warm climates, in intimate association with the decoration of the body, either in the above-mentioned way or by means of ornamental girdles and pendants (fig. 452). Many savages still wear no clothing, and when it is worn it is often so lightly discarded that its primary object is clearly neither protection nor decency.

There are many examples of the painful and DISTORTING PROCESSES to which men will submit under the dictates of custom. In addition to the tattooing and scarring of the skin so frequently found, it is the custom amongst many tribes to perforate the lobe of the ear, and to

POTTERY-MAKING IN CENTRAL AFRICA (LAKE TANGANYIKA)

[By kind permission of Dr. W. A. CUNNINGTON, from original photos.]

Six stages are represented, as follows:—

1. Building up and shaping pot from ring of clay.
2. Pot moulded and allowed to dry a little.
3. Smoothing the under side of a pot.
4. Building up the fire round the pots, which have previously been dried in the sun.
5. The fire alight.
6. The pots after removal from the fire.

POTTERY-MAKING IN CENTRAL AFRICA (LAKE TANGANYIKA)

gradually distend the ring of flesh to such an extent that, when the ear-ring or plug is not being worn, the lobe hangs down even as far as the shoulder. The Australian aborigines, amongst others, perforate the partition between the nostrils, and wear a stick or length of bone or quill in the hole. The lip is perorated by some peoples for the reception of plugs, which may be of large size. In China, ladies' feet are often distorted to reduce their size, the process beginning early in life, and continuing till the habitual gait is a painful hobble. Distortion of the form of the head, characteristic of several uncivilized parts of the world, has been practised even in Europe within recent times. In Europe the constriction of the waist by an adjustable contrivance sometimes leads to serious distortion of the internal organs, whilst the wearing of ear-rings, and the use of face-paint, are further evidences of the survival of savage customs.

Without lingering over the subject of the preparation of SKINS for clothing, which has been practised in Europe almost from the earliest times of which we have any certain record, we may pass on to the consideration of TEXTILES, which are used not only for clothing but for many other purposes.

In the preparation of several kinds of pliant fabrics, such as mats and grass cloths, the vegetable fibres or strips employed are not first twisted together in any way, but in many other cases, both when vegetable and animal fibres are used, a necessary preliminary to plaiting or weaving is the production of a strong yarn by the process known as spinning. The art of SPINNING probably had its origin in the simple twisting together of a number of fibres by rolling them together along the thigh under the hand, and this method is still occasionally employed, as in Australia for example. At a comparatively early period, however, it was discovered that by attaching the beginning of the yarn to the end of a stick, and causing this to spin in the air or along the thigh, the fibres could be spun much more expeditiously. Such a stick is called a SPINDLE, and as a rule it has either a thickened portion near the centre, or is provided with a perforated disc of stone or wood, to cause it to maintain its spin for a longer period. There is usually also an eye or some form of hook at one end for the fixation of the yarn. The wrapping on the spindle is a separate process, which is done at intervals as the lengths of spun yarn are produced. It may be that the origin of the spindle itself is to be attributed to the use of a stick on which to wrap the yarn that had been twisted by the hand. The spindle was known in Europe in the Later Stone Age, and was still in general use not so very many years ago. It may even now be seen in the hands of the peasants in the Pyrenees, in Montenegro, and in other backwaters of European civilization, as well as in such regions as Egypt and Mexico.

By fitting the spindle in horizontal bearings, and connecting it with a wheel for turning, the first SPINNING-WHEEL was produced, and simple forms of this kind may still be found in Europe and Asia. The spinning-wheel, such as was commonly used in Britain in the early part of last century, and is still to be found in parts of Europe, is usually adapted

for spinning the thread and winding it on the spindle at the same time; both hands are free to manipulate the fibre and the yarn, since the wheel is worked by a treadle for the feet. In the modern SPINNING MILL thousands of spindles are worked at once by machinery, but the fundamental idea is the same, and the spindle in a modified form is still the centre of operations.

WEAVING is an art which was probably an offshoot of mat-making. In the production of cloth, whether it be of grass or spun fibre, the materials are soft and pliable, so that some means of holding them taut is necessary. Several uncivilized races, in Africa and America and elsewhere, know how to make grass cloth, or even cloth of spun yarn, and

Fig. 453.—African Loom for Cotton Cloth, Afipa tribe, Lake Tanganyika. (By kind permission of Dr. W. A. Cunnington.)

they employ simple weaving frames on which the warp threads are stretched. The cross threads, or woof, may be worked in and out by means of the fingers (as in mat-making), usually aided by a stick or shuttle. As a rule, however, there is a rod to which some of the warp threads are attached in such a way as to enable them to be easily separated from the rest, so as to permit of the passage of the shuttle across the whole, or a great part, of the width of the warp, at one time. In Europe the chief improvement made until within the last hundred years or so was in the provision of healds or heddles, which are more efficient contrivances for separating groups of warp-strands for the passage of the shuttle. The FLYING SHUTTLE and the levers by which it is driven across the frame are late inventions of civilization, and in modern looms the steam engine does the purely mechanical part of the weaver's work.

In connection with textiles we must refer to the rude kind of cloth made from the inner bark of certain trees, such as the paper mulberry, by

soaking it in water and beating it out upon a wooden table. This bark cloth, called TAPA in Oceania, has a wide distribution, since it is found in Africa, America, Borneo, and many of the islands of the Pacific. It is in reality a natural textile, since the toughness of the cloth depends upon the natural interlacing of the fibres of which the bark is composed.

CHAPTER IV

ORIGINS OF INVENTIONS (*Concluded*)

DWELLINGS.—Man probably inherited an instinct for building himself platforms, if not shelters, of leafy boughs, from his tree-dwelling ancestors, since we know that some of the existing man-like apes have made a first step in architecture of a similar nature. Some South American tribes have no more elaborate dwelling than a sloping screen of palm-leaves leaning against a cross pole attached to two trees. Some neighbouring tribes make a simple hut by sticking a number of the leaves in the ground in a circle, inclining them towards each other so that they meet at the top. The Australian aborigines are scarcely more advanced in their architecture. CONICAL HUTS and TENTS of various materials have a widespread distribution, and the bell tents of a modern army are survivals of this type in civilization. By raising a conical hut on short posts, or on a built-up wall, as is done by many tribes in Africa, more room became available inside, and by an increase in the proportionate height of the wall the hut became merely the roof, whilst the originally subsidiary elevating wall formed the greater part of the house. The circular hut is a primitive type, and the construction of rectangular dwellings (which can be made much larger) is a considerable advance.

As an example of the development of similar features, under similar conditions, in different parts of the world, we may note the PILE DWELLINGS of New Guinea, Borneo, South America, and of prehistoric Europe. These are houses built usually above the water near the shores of lakes and estuaries, their supports consisting of long wooden piles or poles driven into the mud. The primary object is that of safety from marauding enemies, but there are other advantages.

Concerning the use of CAVES and ROCK SHELTERS by prehistoric and modern races nothing need be said, nor is it possible to discuss the question of the replacement of wood, stone, and clay as building materials by baked clay in the form of bricks. It may be mentioned, however, that SUN-DRIED BRICKS have been extensively used in hot and dry climates, such as Egypt, Babylon, and Mexico, by races in advanced stages of culture.

LOCOMOTION AND TRANSPORT.—Travel and transport by land are, amongst primitive peoples, chiefly a question of the endurance of the individual, especially where domesticated beasts of burden are not avail-

able. The various forms of skis and snowshoes help the traveller when conditions are favourable to their use, and the SLEDGE is a conveyance of the utmost value to northern races, such as the Eskimo, whose dogs relieve their masters of the labour of pulling. Perhaps we may find a suggestion as to the origin of the sledge in the former methods practised by some North American Indian tribes, who tied their tent skins and other baggage to the tent poles, which were then dragged along the ground by horses. The Irish slide-car is essentially similar in principle.

But it was the invention of the WHEEL that made rapid locomotion possible under ordinary circumstances. The idea of moving heavy objects by means of ROLLERS placed underneath them is of ancient origin, and it may be that the first wheels originated in the loose attachment of rollers to an object that had to be moved. Ancient wagons, such as were used in Roman times (along with less primitive forms), sometimes had heavy solid wheels made of a piece of tree-trunk cut across, and these wheels were attached in such a way that wheels and axle went round together.

Fig. 454.—Dug-out Canoe crossing a Flooded River, East Central Africa. (By kind permission of Dr. W. A. Cunnington.)

RAFTS, BOATS, and SHIPS are made by most races of man, and from existing types it is possible to trace with unusual clearness the general line of evolution of the more important forms. We may neglect such forms as the bark canoes, and the frame-and-skin kayaks and coracles, since they have not led to the development of any of the more complex modern vessels. It is with the DUG-OUT that the story of the liner or the man-of-war begins, if, indeed, we do not start with the simple logs of wood, in some cases with pointed ends, used in some parts of the world either as a support in swimming (North America) or as a vessel paddled with the hands (Australia). The dug-out, made from a tree-trunk by hollowing out a cavity by means of stone or metal tools, usually after charring by heat, is or has been employed practically all over the world (fig. 454). In Africa, America, and Oceania the type is still widely used; in Europe and Asia it has almost disappeared, and here its origin dates from prehistoric times. The dug-outs of the Pacific often have the sides raised by means of planks

sewn together, and this is the first step in a course of development which leads to the complete subordination of the dug-out to the side planks. The latter become more and more conspicuous, whilst the former, even in many boats from Oceania, is reduced to a mere keel. Thus in one region of the world we get the history of the boat from the hollowed log to the plank boat, and a similar series of changes probably occurred in Europe before the period of history. Similar boats of planks sewn together are found in Africa (fig. 455).

The advance from the boat with sewn planks to that in which nails are used presents no difficulties, even if there had not been found in the East Indies vessels in which the transition is clearly shown. The first nails used were of wood, which were later displaced by those now ordinarily employed in all civilized countries. The growth of the boat into the ship took place long ago, and the history is too complex for discussion here. It is a striking example of the continuity of human invention that the *Dreadnought* and the *Mauretania* are the descendants of the dug-out of the uncivilized prehistoric inhabitants of Europe.

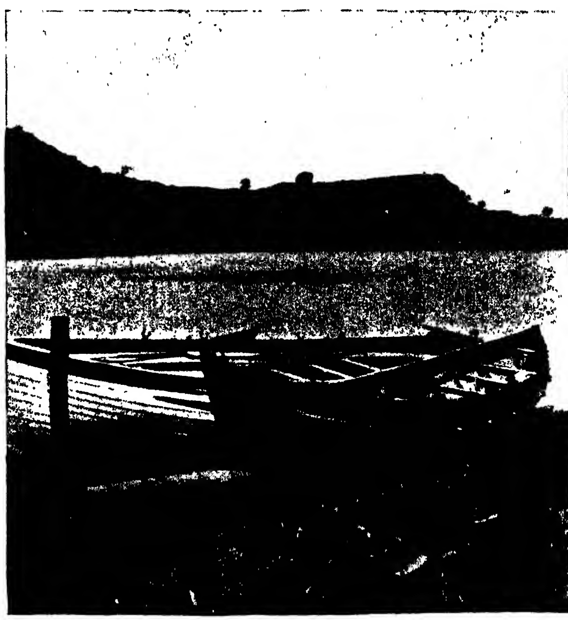


Fig. 455.—Canoe of Planks Sewn Together (to the left a European boat), Victoria Nyanza, Africa. (By kind permission of Dr. W. A. Cunnington.)

MUSICAL INSTRUMENTS.—Most races of man have some form of musical instrument, even if it be only a hollow log for a drum, or a bunch of dried fruits for a rattle. The sounds produced may not appeal to us, but they satisfy the savage sense of rhythm, and serve, amongst other purposes, to increase the excitement of the dance or fight. Many uncivilized peoples, especially in Africa, have a considerable variety of musical instruments, such as drums, whistles, horns, and various stringed instruments.

As an example of the evolutionary process in this field, we may consider the origin and development of one class of stringed instruments. Some South African tribes use the ordinary shooting bow for producing musical notes, a practice no doubt suggested by the twang of the string when an arrow is discharged. The increase in the volume of sound brought about by the attachment of a resonating chamber in the form of a gourd has been discovered by some tribes, and from this stage onwards there is a

practically unbroken line of development. The permanent fixation of the end of the bow to the gourd is a further step, and an increase in the

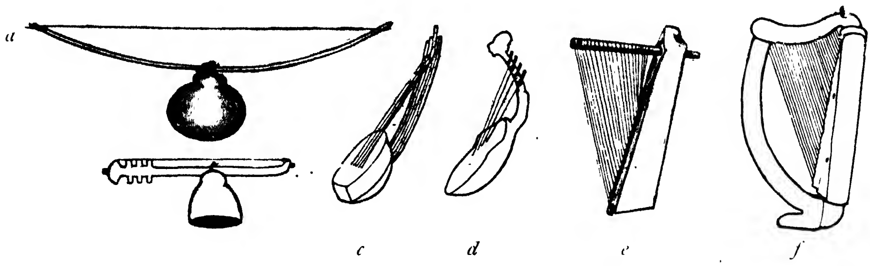


Fig. 456.—Series illustrating the Origin of the Harp

a, Bow with gourd resonator. *b*, Bow with gourd resonator, the bow-stave being inflexible. *c*, Several incomplete bows attached, with their staves, to a wooden box. *d*, Primitive type of harp. *e*, Egyptian harp, without front pillar. *f*, Irish harp, with front pillar. *a* to *d* are from various parts of Africa.

number of bows and strings leads us on towards the harp type. This may be said to be reached when several strings in one plane are attached at each end to a curved frame, as in some African and other harps. The addition of the front pillar has not been made by any uncivilized people, but there is no doubt that the HARP has arisen by steps such as those just outlined (fig. 456). Moreover, the grand PIANO is essentially a harp lying on its side, with an arrangement for sounding the strings by means of hammers. Practically all the stages in this process of development can be traced, though in some cases it is necessary to look in other regions besides Africa for suggestions as to the exact nature of the steps. From the twang of the bow-string of the hunter to the brilliant performances of the modern pianist is an advance in the art of music which has been dependent upon the associated evolution in the instruments employed.

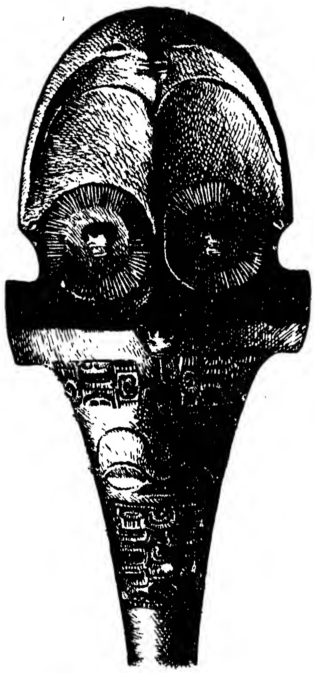


Fig. 457.—Head of a Chief's Polished and Carved Wooden Club, with several human-face designs, Marquesas Islands, Polynesia

DECORATIVE ART.—The decoration of weapons, tools, houses, boats, and other objects by means of carvings or paintings has been or is practised by the majority of races, though there is much variation in the artistic talent manifested and in the kind of work attempted (fig. 457). Apart from the realistic representation of natural objects or living creatures we find that many savage races have characteristic patterns or designs which they use in decoration, and the study of the manner in which such patterns have been arrived at is of the utmost interest. In civilized countries we

live in such an atmosphere of art of some sort or another that it is difficult to put ourselves in the position of early man, who had to discover or invent for himself all his ornamental patterns and designs.

In studying the art of modern savages it is usually found that even simple geometrical elements, such as diamonds, triangles, zigzags, spirals, have a definite history, and that they are in many cases derived from sources which are only traceable in the designs by comparison of a considerable number of specimens, or by enquiry from the natives themselves. Thus in south-east British New Guinea, clubs, paddles, and other objects are often ornamented with a scroll design, which has been shown to be derived from the repetitional representation of the head of a bird with

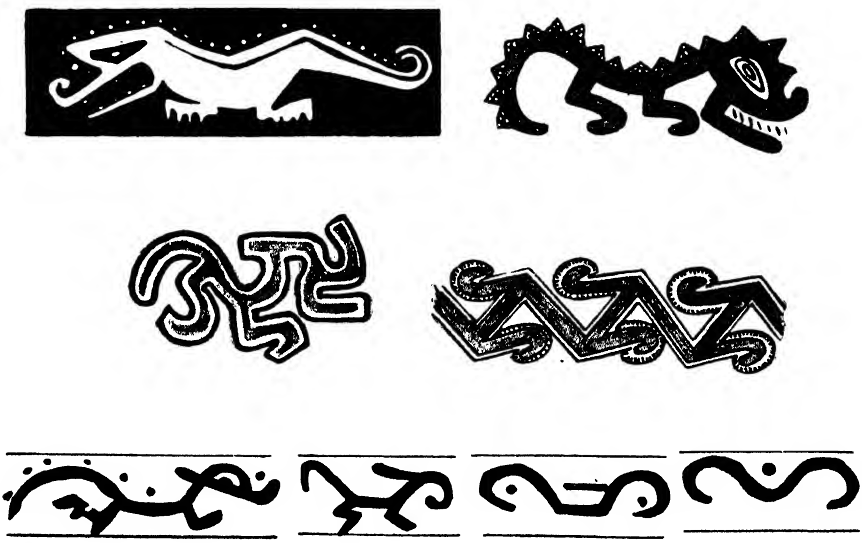


Fig. 458.—To illustrate the evolution of designs. Modifications of the alligator design used in ornamentation by the Chiriqui Indians, Central America (after Holmes, in Sixth Annual Report of the Bureau of Ethnology)

curved beak. On some specimens there is no difficulty in realizing the resemblance, whilst on others it is entirely obscured. This may be described as the origin of a pattern by degeneration of a design, in consequence of repeated copying without reference to the original. The Chiriqui Indians of Central America had many patterns based on representations of the alligator (fig. 458).

Another frequent source of patterns is in the imitation of the appearances presented by plaited basketwork, or by the string-work which is sometimes used to bind the handles or other parts of tools and weapons. Fijian and other clubs from the Pacific are often carved with designs obviously based on the patterns produced by the wrapping of string or sinnet, which is often applied to the handles of clubs, whilst examples of prehistoric European pottery have been found which are ornamented with designs clearly suggested by those produced in the plaiting or weaving of baskets and textiles. There are other methods in which conventional

designs may arise, but enough has been said to indicate that in this subject, as in others, there is definite proof of the continuous nature of the steps by which the evolution of man's creations has proceeded.

COMMERCE.—It is well known that in uncivilized regions commerce is chiefly a question of EXCHANGE or BARTER, and we find at the present day practically all stages between the primitive method of exchange of commodities and that which involves the use of such forms of money as bank notes, cheques, and bills of exchange, which imply a complicated system of credit and reciprocity. The first advance upon barter is when some commodity becomes so far recognized as a MEDIUM OF EXCHANGE in any area that it is used chiefly, though not entirely, for this purpose. The hoe blades of some African tribes, the strings of shell discs (which may also be used as ornaments) of many Oceanic islands, are examples of currency of this kind, the objects deriving their value from their rarity or their utility, or from the difficulty with which they are obtained or made.

By degrees such objects tend to become used only for purposes of exchange, and their nature may also be altered so that they are only conventional representations of useful or valuable objects. This leads to the development of true MONEY, which is not necessarily in the form of coin, though this is the most convenient form. COINS have been used in Europe since classical times, and there is evidence to show that they were originally made to represent standard values, such as that of an ox, which was widely used for expressing values. An ox was regarded as the equivalent of so much gold, and this determined, in some regions at least, the amount of the metal used in making the coin. The British sovereign is derived from coins which can be traced back to others possessed by the Greeks and Romans, and it may therefore be said to have its origin in the relation between the value of gold and the value of an ox.

The system of COUNTING objects by tens, which is practically universally used by races whose arithmetic is so far advanced, has its origin in the number of fingers possessed by man upon his two hands. In many languages the connection is evident, since the word for ten is equivalent to that for two hands, or some similar relationship exists. In some cases the word for twenty is equivalent to "a whole man", that is, all his fingers and toes taken together. Most of our measures of length also are derived from such variable quantities as the height of a man, the length of the foot, the length of a stride.

WRITING.—The history of the art of writing is a fascinating one, and begins with the study of such pictorial art as that of the modern Eskimo, who carve upon their bone and ivory implements small figures of men, animals, boats, and other objects, so as to represent hunting scenes or other events (fig. 459). Amongst some North American Indian tribes true "picture-writing" had been arrived at, certain figures and signs having acquired a definite meaning. In the Old World we find three very characteristic writing systems of ancient origin, each of which can be traced back to the representation of natural objects. These are the hieratic Egyptian, the cuneiform of ancient Assyria and Persia, and the Chinese.

The origin of the first of these can be easily traced to the HIEROGLYPHICS which were employed at the same time. The latter are undoubtedly the older, and in many cases they are recognizable as pictures of such objects as a hawk, a star, the sun, a hand, and so on in great variety. The inscriptions carved in stone are always in hieroglyphics, and so in many cases are those executed on other materials, but in early times the Egyptian scribes, when writing on papyrus, found it too much trouble to draw the hieroglyphics in detail, and therefore reduced them in each case to a few short strokes.

Whereas in Egypt hieroglyphics and hieratics were employed at the same time, in China and Assyria the hieroglyphics became lost in the characters to which they gave rise. The mode of origin of the modern Chinese characters (which are not phonetic) may be compared with that of the Egyptian hieratics, but the CUNEIFORM of ancient Assyria (which has left no modern descendant) arose from the earlier hieroglyphics probably as a result of the use of clay tablets for writing

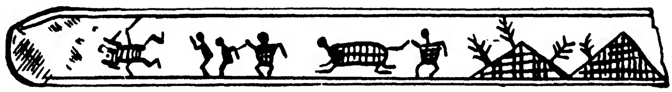


Fig. 459.—Eskimo Engraving on Ivory of a Shaman (medicine-man) casting out Demons. The figure on the left is a demon that has been cast out; the quadruped in the centre is a friendly demon who helps the medicine-man. (After Mallery, Fourth Annual Report of the Bureau of American Ethnology.)

upon when space was limited. Such a material is only adapted for the production of straight lines, and hence the Assyrian characters came to consist entirely of lines without any curves. As a combined result of the writing instrument used—which was square at the end—and of the softness of the clay, the lines assumed a wedge-shaped form, and hence the term cuneiform.

It is not difficult to follow the steps by which an ALPHABET may have arisen from hieroglyphics. In primitive pictorial art each object represented stands for that object, but it easily acquires also a symbolic meaning, as when the battleaxe was used by the Egyptians as a symbol of divinity. But the essential principle of phonetic writing, which is the only kind that is entirely adapted for the representation of spoken language, is to have signs or letters to indicate sounds. An early step in this direction was probably by using the picture of an object, which had, of course, a name of its own, to indicate the sound of a syllable, without reference to its sense. For example, the word *portmanteau* might be represented by a picture of a port, of a man, and of a toe, in the manner familiar to the readers of a certain class of periodical. The ancient Mexicans, who used a form of picture writing, had reached this stage at the time of the Spanish conquest. The characters here represent sounds, which are in this case syllables and not letters, and a writing system in this stage is based on a syllabary, not on an alphabet.

At an early period of their history the dynastic Egyptians had reached the stage when they could, if it had occurred to them, have written their

language phonetically; but as a matter of fact they used in cumbrous combination pictures, syllabic signs, and letters. The letters arose from certain hieroglyphs, by the use of the initial consonant to signify the same sound wherever it occurred. Thus, if we imagine that the English word *day* was represented by a rayed circle, a picture of the sun, and that the same picture were to be used first for the sound of the syllable *da*, wherever it occurred, and finally for the sound *d* under all circumstances, we should have an illustration of the transition of a hieroglyph to a syllabic sign, and thence to a letter.

It was formerly believed that the greater number, if not all, of the existing alphabets of Europe and Asia (with the exception of the Chinese signs) were derived from the Egyptian hieroglyphs, some of the alphabetical forms being adopted and simplified by the Phœnicians, and used as letters to indicate sounds only, and that this alphabet has come down to us through the Greeks and Romans. There is, however, very considerable doubt as to whether the Egyptian hieroglyphs had more than an indirect influence upon the alphabetical system which is the earliest known, and which certainly gave rise to the majority of existing alphabets. This earliest alphabet is found on a monument known as the STONE OF MESHA, and the language is Moabite; there are other inscriptions in the same alphabet, in other Semitic languages, from the same region and of about the same period. Some of the characters resemble certain of the Egyptian hieroglyphs, but the correspondence is not sufficiently close to prove the origin of this old Semitic alphabet from the hieroglyphs. There is no doubt, however, that our own alphabet is derived from the Semitic letters, and the word itself is composed of the names of the two first letters, Aleph (ox) and Beth (house), passed on to us through the Greeks.

Important as was the growth of the art of writing in making permanent man's advances in various fields, the invention of PRINTING played a still greater part in the fixation and dissemination of knowledge. The Chinese appear to have been the first printers, since they were using page blocks probably as early as the sixth century A.D. In this form the invention came to Europe, where it became of much greater value after the adoption of movable types for each letter.

CHAPTER V

THE ORIGINS OF CIVILIZATION—STONE AGES IN EUROPE

In the foregoing pages we have considered the elements of material culture, with especial reference to the origin and development of the artificial appliances which are at once the evidences and the foundation of the various grades of man's material welfare. In dealing with modern races it is

possible to study on the spot the present state of their material, mental, moral, and social culture, and by the aid of history, in the form of contemporary records or traditions, we are often able to carry our researches some way back into the past. In many parts of the world, however, there are found evidences of the existence of men in days long before any history was recorded. These evidences are usually in the form of tools, weapons, and other artificial products, fortunately preserved by favourable conditions, and from the study of them we are able to draw conclusions as to the general conditions of life and state of culture of their fabricators. In Britain, and in Western Europe generally, the relics of prehistoric man are found in such numbers and under such conditions that we are able to trace the gradual increase in this region of man's knowledge of materials, and of his utilization and adaptation of natural products.

The oldest records of man's presence in Europe are implements of stone, usually flint, which so preponderate over all other artefacts that the whole period during which they were made is called the STONE AGE. Other substances, such as wood and bone, were used during a large part, and probably during the whole, of the Stone Age, but of all the materials employed stone is the least liable to decay. The Stone Age falls naturally into two divisions—the Old Stone (or Palæolithic) Age, and the New Stone (or Neolithic) Age. The former is characterized by implements of stone which are shaped by flaking and chipping only, whilst in the latter period the stone implements were often finished by being ground and polished to a smooth edge and surface. As we shall see, there are numerous evidences that the Neolithic people were in other respects in a much more advanced stage of culture than their predecessors.

OLD STONE (PALÆOLITHIC) AGE.—The stone implements of the Palæolithic Age are found in situations indicating that they were made, and discarded or lost, many thousands of years ago. For example, the Thames near Gravesend is overlooked by low chalk hills which are in places capped by deposits of gravel lying about 100 ft. above the present level of the river. These gravels were deposited by the Thames itself when the bottom of the valley through which it flowed was at the height at which the gravels now lie. In the gravels are found numerous flints which have unmistakably been worked by man into shapes adapting them for use as tools or weapons, and all the evidence goes to show that the implements are of an age at least equal to that of the gravels. Along with the implements are found the bones and teeth of animals, such as the mammoth, which have long been extinct. In other parts of the South and East of England, and also in France and elsewhere, similar evidence of the antiquity of man is forthcoming, and indeed many observers believe that certain stones, which have received the name of EOLITHS, were shaped by man at a period long antecedent to the deposit of the river gravels. That the eoliths are really artefacts is not by any means universally believed, though the Palæolithic implements are in many cases of such fine workmanship that man had probably undergone an apprenticeship to the art of stone-working which may have been of very long duration. However

this may be, the Palæolithic implements give us absolutely certain proof of the existence of man.

Like the Stone Age, of which it is a subdivision, the Palæolithic Age is itself divided into two parts, the River-drift (or simply Drift) Period and the Cave Period. Confining ourselves for the present to the DRIFT PERIOD, to which belong the implements found in river gravels and similar situations, the numerous implements that have been found, afford indications of the habits and the mode of life of the men who made them. The types of implements show considerable variation in size and shape.

Most characteristic of all is what is variously called tongue-shaped,

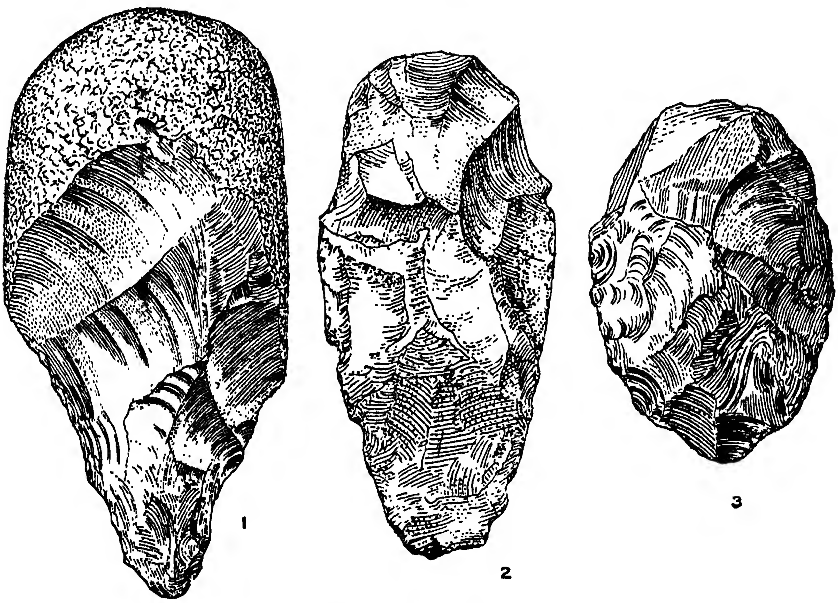


Fig. 460.—River-drift Implements

pear-shaped, or the COUP-DE-POING (fig. 460, 1, 2), which is an implement with a thick butt suitable for grasping in the hand, and with the other extremity tapering to a cutting or piercing point. In some cases the implement is thinner in the butt, and may have been fixed to a haft for use as a spear-head, a dagger, or even as a war-pick or tomahawk. We have, however, no definite proof that any of the flint implements of river-drift man were hafted, though in all probability he used wood for clubs and spears as well as for many other purposes.

Another very characteristic form of flint implement is what is often called the OVATE SHARP-RIMMED IMPLEMENT (fig. 460, 3), which is usually more highly finished than the tongue-shaped, and points to an advance in skill. This form as a rule seems ill adapted for use in the hand, since in typical examples there is a sharp edge all round, and the form is flattened. It may therefore have been hafted for use as a knife or as a double-edged

axe, and some forms are even more suggestive of spear-heads than are any of the tongue-shaped examples.

The other principal implements of the River-drift Period are the CHOPPER or thick-backed flint knife, which could be used for hacking, chopping, and cutting without any necessity for hafting; the SCRAPER, with a thick crescentic edge, no doubt used for the cleaning of the under side of skins; the BORER, for perforating wood, bone, skin, &c., for various purposes; and the HAMMER-STONE, an essential implement for the working of flint. It was with the hammer-stone that River-drift man, like his successors in later periods of the Stone Age, and like some modern backward races, broke away splints or flakes of flint from selected blocks, and so shaped the stone to the form of the implement required.

The evidence we have concerning the men of the River-drift Period justifies us in concluding that they were what we should call savages. They lived chiefly by the products of the chase, and in general culture they were probably about on a level with the existing aborigines of Australia. We have no evidence that they cultivated the soil, nor that they had domesticated any of the wild animals which they hunted and devoured. We cannot say for certain that they had a knowledge of fire, but it seems probable that this was the case. They no doubt clothed themselves in skins, and they may have built shelters or huts of simple construction. From the few remains that have been found it appears that River-drift man was of a low type, with retreating forehead, projecting jaws, receding chin, and prominent brow ridges; but he was unmistakably a human being, and little if any lower in type than several existing races of man.

The distinction between the River-drift and the succeeding CAVE PERIOD is much less clear in England than in France. Various caves in England were occupied by Palæolithic man, and the implements he made are found buried many feet below the present level of the floor of the caves. Brixham Cave and Kent's Cavern in Devonshire, Wookey Hole in Somersetshire, and caves at Creswell Crags in Derbyshire, amongst others, have yielded important finds of this remote period. Many caves and rock shelters of France, especially those of Dordogne, were certainly occupied by Palæolithic men in a higher stage of culture than were their predecessors of the earlier period. Beginning with a transitional period, the Mousterian, and passing through the Solutrean to the Madelainean, we can trace a gradual increase of skill in the working of flint, which culminated in the Solutrean and declined in the Madelainean.

The typical pear-shaped implement of the River-drift Period disappeared during the MOUSTERIAN EPOCH. Characteristic chopping, scraping, and pointed cutting tools were produced, and it is possible that some of the latter were mounted as spearheads. During the SOLUTREAN EPOCH (named after the rock shelter at Solutré, Saône-et-Loire) beautiful thin flat blades of flint were made, which can scarcely be surpassed by any implements of Neolithic man. These leaf-shaped blades were no doubt hafted, some probably as knives, others as spear-heads, or possibly even arrowheads. Bone and reindeer-antler were beginning to be used for the heads

of spears and for other purposes. In the MADELAINEAN EPOCH (named after the cave of La Madelaine, Dordogne) the flint implements were of few types, and comprise chiefly small tools, such as scrapers and gravers. Bone and reindeer-antler were, however, much used for the points of spears and harpoons (and perhaps arrows), and for needles and borers. Spear-throwers, not differing essentially from those of the modern Australians or Eskimo, but made of reindeer-antler, are also found. The epoch is especially remarkable for the great development of realistic art, which manifested itself in the carving of the figures of animals on or in bone, ivory, and stone (fig. 461), and the painting and engraving of them on the

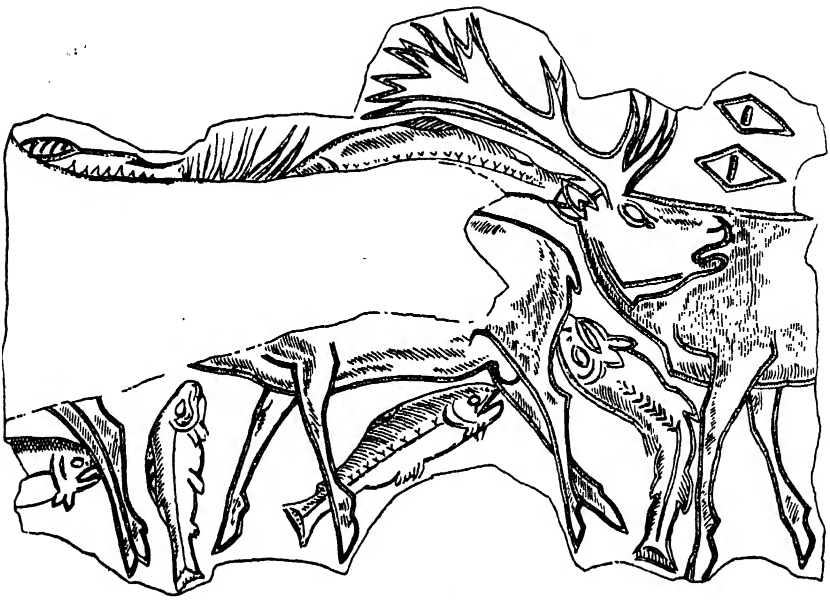


Fig. 461.—Carving of Reindeer and Salmon on Bone, France, Cave Period (from *L'Anthropologie*, after Piette)

walls of caves (fig. 462). The horse, the reindeer, the mammoth, the ūrus, the bison, the rhinoceros, various kinds of deer, and many other contemporary animals were carved and engraved, and representations of man himself are sometimes found.

We cannot doubt that the men of the Cave Period were in a higher stage of culture than were those of the River-drift; the arts of spinning and weaving, of pottery-making, and of agriculture were, however, still unknown, and they do not appear to have possessed any domesticated animals, with the possible exception of the horse, which may have been partially tamed. The Cave men are often compared with the modern Eskimo, whom they resembled in several respects, especially during the Madelainean Epoch, when the climate of Southern France was similar to that of the arctic regions occupied by the Eskimo. Like the latter, the Cave men decorated their implements with carvings, made extensive use of bone and ivory, dressed in skins, and lived by the products of the

chase. Some of the bone spear-heads of the Cave men are practically identical in form with those of the Eskimo, though we cannot say whether the entire weapons were as ingenious in construction as are those of the latter. In his physical structure the remains that have been found indicate that the Cave man was of a higher type than his predecessors of the drift.

The Palæolithic Age had a duration which is very variously estimated. Some investigators believe it to have begun between 250,000 and 500,000 years ago; others reduce it to 100,000, or less. In any case it is regarded as having been entirely confined to the Quaternary or Pleistocene geological Period, whereas "eoliths" have been found in deposits of the Tertiary Period. The Palæolithic Age witnessed many changes in the configuration of the land of Western Europe, Great Britain during a portion of the time being connected with the Continent.

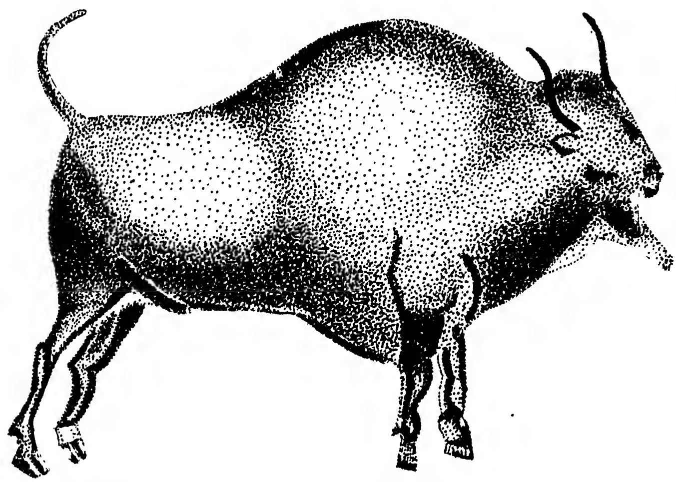


Fig. 462.—Painting of Bison on Wall of Cave, France, Cave Period (from *L'Anthropologie*, after Cartailhac and Breuil)

The palæolithic age was in part contemporaneous with what is known as the GLACIAL PERIOD, when ice-sheets and glaciers covered the greater part of Great Britain and Northern Europe, whilst glaciers from the Alps, the Pyrenees, and other ranges of mountains extended far into the plains. Whether man lived in Europe through the whole of this Ice Age, or whether he arrived during one of the milder periods which intervened between the several epochs of glaciation, has not been determined with certainty. We know that he lived amongst animals very different from those existing in England and Western Europe at the present day. The cave-lion, the cave-hyæna, the woolly rhinoceros, the hippopotamus, the elephant, were then found in Western Europe, and suggest a warm climate; whilst the musk-sheep, the reindeer, the mammoth, indicate a colder epoch. There are also temperate forms, such as the horse, the bison, and the wolf. This intermingling of tropical, arctic, and temperate species has not yet received satisfactory explanation, though it supports the evidence as to the variations in climate.

New Stone (Neolithic) Age.—With the New Stone or Neolithic Age we enter upon a period which brings us by gradual stages to conditions which approximate to those with which we are now familiar. 'In the Old Stone Age all seems strange—the climate, the animals, and the configuration of the land. At the opening of the New Stone Age the climate was temperate, the animal and plant life was essentially similar to that of the present day, and Great Britain was finally an island. It is very generally held that there is a considerable gap in our knowledge of man in Western Europe, or at any rate in Great Britain, previous to the beginning of the New Stone Age. The implements and other relics discovered do not enable us to bridge over the gap between Palæolithic and Neolithic man, especially if we take into account arts and crafts other than that of stone-working. Even the continuity of the stone-implement types cannot be satisfactorily demonstrated, though the evidence for a gradual transition in France is accepted as adequate by some investigators.

The New Stone Age is sometimes spoken of as the Age of Polished Stone, for the reason that for the first time we find implements finished by grinding and polishing, though many were still completed without undergoing these processes. Neolithic implements are widely distributed over Great Britain and Ireland and over the whole continent of Europe, whereas Palæolithic implements are not found in Ireland, Scotland[1], the North of England, nor in Scandinavia and Northern Europe generally. Neolithic implements occur on or near the surface of the ground, at the bottom of lakes or rivers, in bogs, in graves or sepulchral mounds. They are therefore of much less antiquity than the Palæolithic implements, a conclusion which is supported by the less altered condition of the flint of which they are often made, as well as by the fact that they are not found in association with the bones of extinct animals.

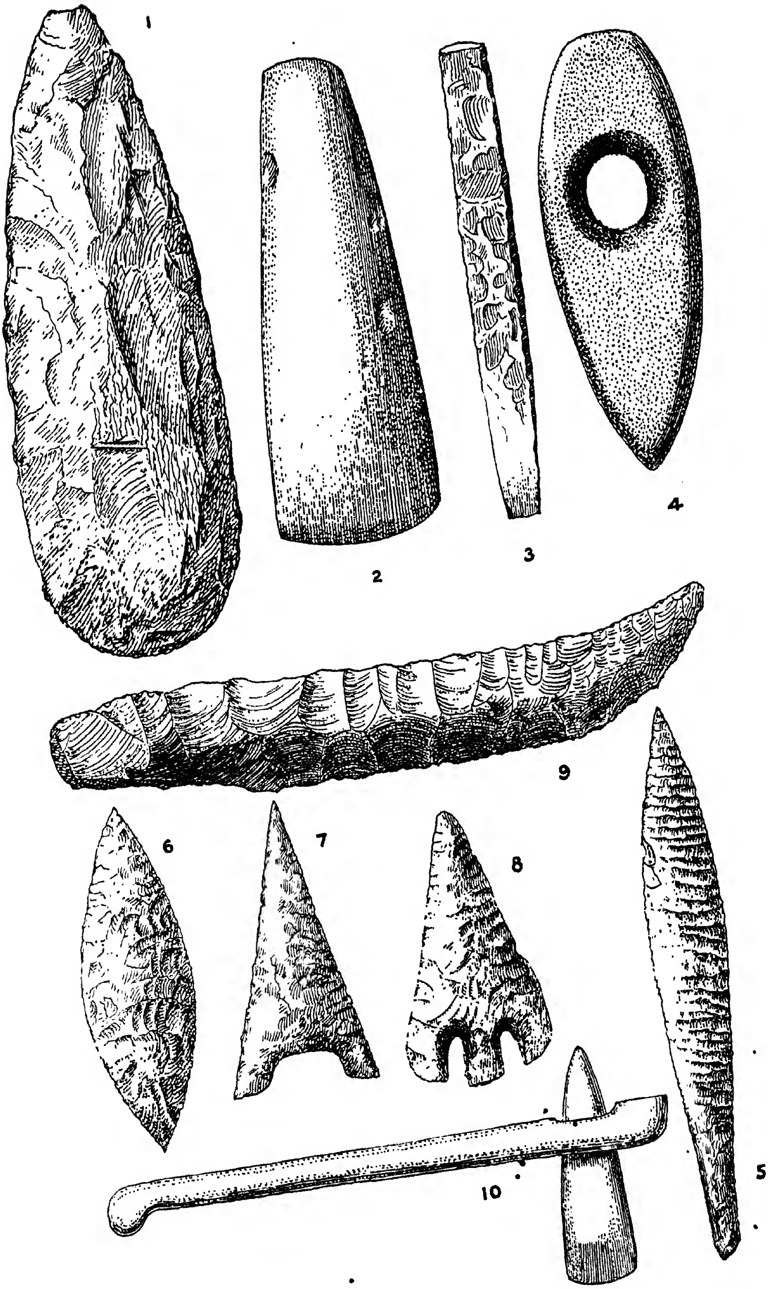
The stone implements of Neolithic man approximate much more closely to those of modern stone-using races than do the implements of the Palæolithic Age. Thus we may recognize amongst them, in addition to choppers, scrapers, and hammer-stones, not differing essentially from those of the earlier period, forms which can be identified as axe-heads, adze-heads, gouges, chisels, knives, arrow-heads, and spear-heads (see Plate); and in some instances the stone implements have been found still connected with the wooden hafts in which they were mounted for use. In addition to stone, Neolithic man made use of bone, which he made into chisels, awls, needles, and spear-heads, and he employed the antlers of deer for picks, hammers, and other implements. Neolithic man often lived in villages, which in some cases consisted of a number of houses built on piles at the margins of lakes and rivers. From the remains of the numerous pile-dwellings of the Neolithic men who lived in this way in the Swiss lakes, we know that he made pottery, kept domesticated animals, such as the horse, the ox, and the sheep, cultivated the soil and grew millet, wheat, and barley, spun yarn from flax and the hair of animals, and wove garments and made nets from his yarn. Similar evidences of culture have

[1] Good evidence has been brought forward by the Rev. F. Smith, of South Queensferry, to negative the general view as regards Scotland.—Ed.

NEOLITHIC IMPLEMENTS

1, Unpolished axehead, Anglesey.
2, Polished axehead from the Thames at Erith.
3, Flint chisel, Denmark.
4, Perforated axe-hammer, Exmoor.
5, Flint knife or dagger, showing "parallel flaking", Denmark
6 and 7, Flint arrowheads, Ireland.
8, Flint arrowhead, Cornwall.
9, Flint knife, Greenwich.
10, Stone axehead in haft, England (restored).

(From specimens in the British Museum and the Museum of Practical Geology).



NEOLITHIC IMPLEMENTS

been found in other regions, supporting or amplifying the conclusions derived from the Swiss lake dwellings.

In the British Isles and on the Continent the so-called "HUT CIRCLES" indicate that dwellings were sometimes built with a supporting ring of stones, the floor of the hut being often sunk below the level of the ground, and the walls and roof probably consisting of poles or beams connected by wickerwork filled in with clay or turf.

Neolithic man sometimes cremated his dead before burial, and sometimes omitted the cremation. He erected sepulchral mounds, which are known as LONG BARROWS, and were probably tribal burying-grounds. He erected huge stone structures, sometimes as chambers for the dead, some-

Fig. 463.—Dolmen of Kergavat en Plouharnel, Brittany

times apparently as religious edifices. The DOLMENS or CROMLECHS (fig. 463), consisting of two or more large upright stones supporting a flat capstone, were often, if not always, buried by an artificial mound (long barrow), and contained the remains of the dead. Other megalithic structures are the MENHIRS, or large elongated upright stones; the rows of upright stones or ALIGNMENTS; and the STONE CIRCLES. The stones or blocks used are often of such huge size that their erection is evidence not only of mechanical skill, but of a habit of co-operative and well-organized labour. Stonehenge, in England, and Carnac, in Brittany, are two of the most wonderful of the erections of Neolithic man.

The ART of Neolithic man shows none of the realistic tendencies which dominated that of the Cave men. Geometrical designs, made up of lines and dots, cross hatchings, zigzags, chevrons, and other simple elements, predominate. In some instances the designs are clearly suggested by the patterns produced in the plaiting or weaving of textile materials.

CHAPTER VI

THE ORIGINS OF CIVILIZATION (*Continued*)—METAL AGES IN EUROPE—EARLY CIVILIZATION IN EGYPT, ASIA, AND AMERICA

The possibilities of advance in culture are limited in the case of races having no knowledge of metals. With material that can be made into almost any shape, and that will take a sharp and resistant edge, it is possible to work more quickly and more effectively, whilst many new types of tools and other appliances come within the scope of invention. Although copper is a soft metal, it has many advantages over stone, and its superiority is increased by the addition of a small proportion of tin. It is now established that in several parts of the world the first metal utilized by man was copper, which occurs in a more or less pure state in many regions. It is, moreover, often of a striking appearance, and nothing is more natural than that Neolithic man should try his hand at making implements of this attractive kind of "stone". He would soon discover that although he could not chip it into form, the material was so soft that it could be hammered into axe-heads or spear-heads similar to those of stone. Although we cannot say definitely that this was the mode of the discovery of the nature of copper in Europe, it certainly appears to have been the case in part of North America, where the Indians, in all respects still in their Stone Age, made implements by simply hammering the native copper which they discovered and experimented upon.

If we suppose that in Europe (or in Asia, or wherever the locality may have been) copper implements were first made in this way, it is easily conceivable that the melting of the metal was first observed in consequence of the accidental dropping of a copper implement into the fire. That it melted and assumed another shape could not fail to attract the attention of the observant savage, and he would be led to make attempts to determine the shape assumed by the molten metal. In this way the art of casting may have been invented, and the basis of metallurgy established. In several parts of Europe there is evidence that an Age of Copper was passed through, though it was probably of short duration.

How and where the advantage of hardening the copper by an admixture of tin was discovered is not known, but this alloy, which is called BRONZE, was known in Western and Central Europe about 2000 B.C. Amongst the chief bronze implements that have been found are axe-heads, chisels, spear-heads, knives, sickles, daggers, swords, mace-heads, shields, and trumpets. This list alone gives some idea of the advance that was made in the implements of culture and in the weapons of war. The sword, for example, is quite a new weapon (no doubt derived from the dagger), since stone is entirely unsuited for the production of long sharp blades. Although bronze was now generally used, stone was still largely employed, arrow-heads, for example, being usually made of flint.

In general culture the people of the Bronze Age, as far as can be ascertained, do not appear to be notably in advance of their predecessors, but we cannot doubt that fuller evidence would show that the greater possibilities opened up in the arts of life by the use of metal formed the basis of a general advance. That the possession of metal tools and weapons is no guarantee of culture may, however, be realized by a study of the savagery of most African negro tribes, who have used iron for at any rate many hundreds of years. The skulls of Bronze Age man are usually of a type which indicate that their former owners were probably of higher mental ability than the negro, since they are lacking in the characteristics which are associated with the lower races. Bronze Age man was no doubt a barbarian, but he possessed the ability, the culture, and the social organization which enabled him to aid in the foundation of modern European civilization.

The men of the Bronze Age buried their dead, either unburnt or after cremation, and raised over them the burial mounds which are known as ROUND BARROWS. The ashes of the cremated bodies were often placed in or beneath urns, and in the grave were deposited tools, weapons, and utensils. The reason for this practice is no doubt to be found in the belief, common to many modern peoples, that the deceased would be benefited by the possession of the objects buried with him, and we may therefore conclude that some kind of future life, resembling life on earth, was anticipated.

EARLY IRON AGE.—To bronze succeeded iron and steel, the early period of the use of iron in Europe being usually called the Early Iron Age. The discovery of this metal may have been made as a result of experiments on iron ores, during attempts to ascertain what other materials would melt by the action of heat. Bronze was only displaced by iron in a very gradual manner, and the former long continued in regular use for the manufacture of personal ornaments, and for decorating shields, swords, wooden vessels, and other objects. In the greater part of Europe iron appears to have been in use by about 600 B.C., but in the more advanced classical lands of Eastern Europe the Bronze Age probably came to an end at an earlier period.

In man of the Early Iron Age in Western Europe we still have the warrior and the barbarian, but he had advanced considerably beyond the stage of his predecessors. His weapons, tools, and other simple appliances were more like those of modern times, and in the direction of art he had produced a style which gave rise to many beautiful designs and ornaments. Agriculture, spinning, weaving, pottery-making, and the other arts of his predecessors were practised by him. The pottery was much superior to that hitherto made, both in material and form, the improvement being no doubt due to the use of the potter's wheel. In metal work he was highly skilled, and he decorated numerous objects with graceful flowing curves and rounded surfaces executed by the repoussé method. Works of art in wrought iron were produced, and the processes of chasing, engraving, and enamelling were practised. The Early Iron Age in Britain is often spoken of as the Late Keltic Period,

and it lasted until the Roman conquest in England, persisting till later times in Scotland and Ireland.

THE HISTORIC PERIOD.—The progress of culture in Western Europe from the Roman Conquest to the present day is too complex for discussion in the present sketch. In England much was learnt from the Romans, though no doubt a large part was swept away by the Anglo-Saxon invasion. The slow and steady growth in knowledge and culture proceeded with few set-backs until the nineteenth century, when the great achievements of science brought about a change incomparably more important than all the discoveries and inventions of the preceding 2000 years. Steam and electricity have stamped modern civilization with a seal that distinguishes it absolutely from all the civilizations that have gone before.

EARLY CIVILIZATION IN EGYPT AND ASIA.—Long before there was any indication of the dawn of civilization in Western Europe, and whilst all this region was still the scene of migrations, conquests, and tribal warfare, there had arisen in several favoured areas of the Old World relatively settled conditions of life, associated with a high degree of culture. In Egypt, Crete, Babylonia, China, and India civilizations had developed, which in the case of the first two named had a great influence on the later civilizations of Greece and Rome. Modern Europe owes much to Greece and Rome, especially in the Mediterranean area, though in North-Western Europe the culture is largely indigenous.

The civilization of EGYPT provides us with by far the most complete record of advance from the lower to the higher grades of culture, and we may therefore consider how far it supports the general theory of the gradual progression of man's capabilities and knowledge. What are probably to be regarded as the earliest records of man's presence in Egypt are stone implements resembling very closely those of the European Palæolithic Age, though they have not yet been conclusively shown to be of equal antiquity. As in Europe, the makers of these implements were apparently a race of hunters in a low stage of culture.

As in Europe, again, these people gave place to men who constructed stone implements of more efficient and more numerous forms, and who were familar with pottery. The period of the arrival of this race can be dated to about 8000 B.C., and from this time onwards there is no break in the continuity of the development of culture. Flint long remained the chief material for tools and weapons, but there were many advances in the working of the material. Spinning and weaving of linen became known, regular houses were built of sun-dried bricks, and large boats were constructed. Hieroglyphs were not known, but a syllabary of writing signs was employed, perhaps even in commercial transactions with other Mediterranean peoples. It seems likely that during this prehistoric period the original invaders were conquered by an allied people in a higher stage of culture, and that many of the advances made were due to these intruders.

Somewhere about 5000 B.C. yet another invasion took place, probably from the East, and it is with this new race that the historic period begins.

The prehistoric civilization had already begun to decay, but the invaders, who are usually spoken of as the *dynastic race*, were already in a high stage of culture. They were possessed of great artistic ability, and developed a system of hieroglyphics. Spinning, weaving, pottery-making, agriculture, and other arts and crafts were practised, and at a later stage their architecture developed to an extent which led to the building of the pyramids, about 4000 to 3700 B.C.

Although copper had been known from about 8000 B.C. in the prehistoric period, bronze only came into extensive use about 1500 B.C., and it remained the chief useful metal until Roman times, though iron was used for knives about 800 B.C. Thus, as regards the succession of stone, bronze, and iron, the steps appear to correspond fairly well in point of time with those of Western Europe, and indicate the probability of a common source of the knowledge of the metals. During the dynastic period a complex state of society was evolved, with courts and armies, trades and professions, but it was all based upon the fertility of the Nile valley and its power of producing food for a large population. With many fluctuations the civilization of Egypt persisted until our own times, though the country has many times undergone a change of rulers, and is now benefiting by the discoveries of the younger and more virile culture of Europe.

MEXICO.—Whereas the Old World, especially the Mediterranean region and Asia, witnessed the growth of several early advanced civilizations, in the New World there have only been two instances of the origin of indigenous cultures worthy to be called civilizations. Mexico and Peru are the best-known centres of these cultures, and at the time of the Spanish conquests a considerable degree of civilization had been attained. In Mexico agriculture and irrigation were practised; highways were made and bridges erected, there was a regular postal service; cotton was spun and woven; gold and silver were used for ornaments; stone buildings of imposing grandeur were erected. There was a hieroglyphic system of writing, and paper was made for the purpose of bearing historical and other records. In spite of all these advanced arts the Aztecs of Mexico were still in their Age of Stone, although they occasionally made use of copper and possibly of bronze.

PERU.—In Peru also, agriculture, irrigation, spinning and weaving, and other arts were practised. Pottery was highly developed, though the potter's wheel does not appear to have been known. Gold, silver, and copper were used, and, to a limited extent, bronze. As in Mexico, there was a strong government and a stable condition of society. In a general way the civilizations of Mexico and Peru, especially of the former, may be compared with that of Egypt in early dynastic times, though in America the indications of artistic and intellectual power were less marked.

FACTORS OF CIVILIZATION.—When we consider the causes that have led to the development of civilizations, we realize that, although much depends upon the mental capacity of the race concerned, other factors play a very large part. The climate, and the possibility of obtaining an

abundance of food by the cultivation of plants, especially cereals, have to be taken into account. Only by means of agriculture is it possible to feed the large populations whose co-operation leads to a definitely organized state of society. Most of the ancient civilizations of the Old World arose and reached their highest points in highly fertile river valleys: the Lower Nile, the Tigris and Euphrates (Mesopotamia), the Ganges, and the Yang-tse-kiang fostered the civilizations of Egypt, Babylonia, India, and China. These all arose in the warmer parts of the temperate zone, in regions where nature was kind, but not too kind. Effort was needed to cultivate the land, so that man was stimulated to invention; the success of his endeavours encouraged him to further efforts, and he also obtained leisure and wealth for the cultivation of the less material arts, and for intellectual pursuits. Except in America, where a high altitude tempered the effects of the sun, no civilization has arisen in the tropics, nor do the polar regions afford us any examples of the development of advanced culture.

It is sometimes said that civilization may be regarded as beginning with the art of writing, by means of which history, law, and knowledge may be recorded for the preserving of the continuity of advance, and the binding together of the past and present. The art of writing (and printing) has undoubtedly been of vast importance, especially in the development of modern European civilization, but it is scarcely advisable to fix such an arbitrary and definite lower limit to the beginning of civilization. The growth of civilizations has in all cases been associated with the progress of arts and crafts, such as agriculture, spinning and weaving, pottery-making, and other activities which, as we have seen, arose from the simplest and most natural beginnings. Means of transport and communication, fixed media of exchange (or money), and other factors affecting the social and commercial life of the community have had great importance, whilst the production of characteristic styles of art, such as the Egyptian, the Assyrian, or the Greek, may be regarded as effects rather than causes of civilization, though they have had their influence in promoting the advance. Poetry and the drama, like painting and sculpture, are represented in some form or another amongst most races of man, but it is in civilized communities that they reach their highest and most differentiated expression.

Religion also, which is represented in its lower stages by the animism, fetishism, and magical practices of savages, becomes more rational, at any rate in theory, in civilization, although it is by no means true that the civilized condition is a safeguard against superstition. A belief in charms and amulets, for example, is still widespread amongst the ignorant, even in Britain, and much more so in the Mediterranean countries of Europe.

Into the question of the origin of man's social instincts it is not possible to enter, nor can we discuss such important subjects as the growth of tribes into nations, and the origin of government. It may be said, however, that for the existence of social groups of all grades it is essential that some security of person and property shall be assured by custom or law. To determine and enforce these laws a government of some

kind usually exists, either in the form of an autocratic chief, a council of elders, a representative elected assembly, or some combination of these. The civilized state, more than any other, requires a settled government; but in the end this can only codify and enforce the laws based upon public opinion, which is an expression of the general ethical standard of the community. In this respect, as in all others, civilizations have been of gradual growth, and various standards have been arrived at in different regions.

CHAPTER VII

THE RACES OF MAN

In studying the existing peoples of the earth, with a view to ascertaining their interrelationships, it is necessary to decide what characters can be relied upon as criteria of race. In a mixed people—and all living peoples are mixed—it is by no means an easy matter to read the riddle of racial admixture, and even approximate results must be obtained by a careful study of many individuals. In addition to physical characters, account must be taken of temperament, language, and culture, whilst tradition and history may give valuable aid. It is first necessary to consider the principal characters that are taken into account by the physical anthropologist.

CRITERIA OF RACE.—Certain of the more obvious characters of man are widely used as racial criteria by the ordinary observer, who may not, for example, endeavour to conceal his repugnance for the "black man" of whatever shade. SKIN COLOUR is a conspicuous but unreliable character in studying race, and the wide variations are only roughly represented by the terms white, yellow, red, and black, which are so often used. Colour of hair and eyes is principally serviceable with regard to the interrelationships of the fair-whites of Europe, since elsewhere there is a general uniformity, both hair and eyes being usually black in other peoples.

A character which is often used to divide mankind into three main groups is the nature of the HAIR. In the *Ulotrichi*, or woolly-haired races, the hair is characterized by numerous close spirals. Hair of this type may be long, as in the Papuans; shorter, as in the Negroes; or very short, as in Bushmen and Negritoes. In the *Cymotrichi*, or wavy-haired races, the hair is undulating, or it may form more or less perfect spirals or curls. In the *Leiotrichi*, or straight-haired people, the hair usually falls straight down from the head. It may be noted that woolly hair is a flat oval in section, whereas straight hair is round, and the various degrees of wavy hair show intermediate sectional forms.

STATURE is a character which requires to be taken into account. The average for the race is 5 ft. 6 in.; those peoples with an average of 5 ft. 8 in. are tall, and those below 5 ft. 4 in. are short. The term PYGMIES is often used for those with an average below 4 ft. 9 in., or sometimes 5 ft. The

general shape of the head and the brain-case, the form of the nose, the shape and thickness of the lips, are characters to be noted. A receding chin, a protruding jaw (PROGNATHISM), strong brow ridges, and a receding forehead are amongst the characters which are regarded as indicating lowness of type, since they are found in the skulls of the apes.

Practically all the above characters are such as can be studied to a certain extent without the aid of measuring appliances. The physical anthropologist, however, is not content with this, but measures and correlates lengths, angles, and capacities in such a way as to be able to express in numbers such characters as the degree of prognathism, or relative breadth of nose. A much-used ratio is that between the breadth of the head (or skull) and its length from back to front. This is called the CEPHALIC OR CRANIAL INDEX, and it expresses in figures the narrowness or roundness of the skull. Individuals (or peoples) in which the breadth

a *b* *c*

Fig. 464.—*a*, Brachycephalic, *b*, mesaticephalic, and *c*, dolichocephalic skulls, seen from above

of the skull is to the length as 75 (or a lower number) is to 100 are called *dolichocephalic* (long or narrow-headed); when breadth is to length as 80 (or some higher number) is to 100 they are *brachycephalic* (short or broad-headed); whilst when the ratio is between 75 and 80 the term used is *mesaticephalic* (medium-headed) (fig. 464). Large groups of men living in one region may agree in being either brachycephalic, mesaticephalic, or dolichocephalic, but it is often found that within the limits of a nation, or even of a tribe, all these conditions occur. Such variation is regarded as an indication of incomplete racial admixture. Some recent observers attach little importance to the cranial index, however.

Another feature to which methods of measurement are applied is the CAPACITY OF THE SKULL, which affords evidence of the size of the brain it formerly contained. The capacity is estimated by filling the cranial cavity with small shot or seeds. It is necessary to point out that cranial capacity is not an exact measure of mental ability.

CLASSIFICATION OF RACES.—Many attempts have been made to draw up a satisfactory classification of the races of mankind, and stress has been laid upon various features by different investigators. The nature of the hair, that is, its degree of curliness or straightness, affords a basis for the

main grouping, since in a general way races which agree in this character tend to agree in others. Thus, negroid races have woolly hair, Mongoloid races have straight hair, and races with wavy hair usually present characters such as we see in the modern European. The crossing of races has, however, been going on for many thousands of years, with the result that pure types are not to be found. The lowest races will here be treated first, and the highest last, but it is not suggested that the order in which they are given indicates the "line" of evolution, since of this very little is known (for chief types see the coloured Plates RACES OF MANKIND, I and II).

The PYGMIES, who are found in the forests of equatorial Africa and in parts of the Malay Peninsula, in the Philippines, and in the Andaman Islands, are distinguished from all other races by their shortness of stature, which in typical groups is on the average below 5 ft., and may be only a little more than 3 ft. The AFRICAN PYGMIES, or NEGRILLOES, comprise the Akkas, the Batwas, and other tribes. They are of a yellowish-brown colour, and have very short woolly hair, usually rusty brown in colour. Their jaws are frequently protruding, their nose very broad and extremely flattened at the root, and their body often hairy, all these characters suggesting lowness of type. They wear no clothes, and have no domesticated animals. They live by collecting and hunting, their chief weapons being the bow and arrows. They are musical and intelligent, but they are not known to have any religion. The Semangs of the Malay Peninsula, the Aetas of the Philippines, and the Andamanese, are collectively called the NEGRITOES. The Andamanese are especially interesting, both as regards the relative purity of the race and their state of culture. They are hunters and collectors of food, and originally they made considerable use of shell (and not stone) for their tools and weapons.

AFRICAN RACES.—The BUSHMEN of South Africa, who have yellow skin and very short woolly hair, may be related to the Negrilloes of the centre of the continent. The average stature is a little over 5 ft. The skull is very small, and the cranial index 76 (mesaticephalic). The nose is extremely broad (platyrhine). They are nomadic hunters, living in portable huts or in caves, and their chief weapon is the bow and arrows, the latter being poisoned. For digging up roots, and for other purposes, they use a stick with a perforated stone at the upper end for a weight. They formerly showed much artistic skill in the decoration of the walls of their caves with representations of men and animals, in style and technique of their paintings bearing considerable resemblance to those of the cave-men of Palæolithic Europe. At one time they extended much farther north than they do at present. Owing to the war of extermination carried on against them, both by white men and other natives, during a large part of last century, there are now very few Bushmen in existence.

The HOTTENTOTS are related to the Bushmen, and they may represent a cross between these and other African races. They are brachycephalic, with prognathous jaws and small chin. Unlike the Bushmen, they owned cattle and sheep.

Negroid races are found over a wide area in Africa and Oceania. The

TRUE NEGROES of Africa occur chiefly in the Sudan, on the Guinea Coast, and in the region of the Upper Nile. The skin is so dark as to be often called black, and the hair is woolly. Their stature is tall or medium. They are dolichocephalic and are frequently prognathous. The nose is flat and broad, the lips thick and often everted. Their arts and crafts are numerous; they possess domesticated animals, such as the dog, goat, pig, and hen, and they cultivate such plants as gourds and bananas. They work iron for swords, daggers, spear- and arrow-heads, &c. Their religion is a mixture of fetishism and ancestor worship, and it often involves ruthless cruelty in the way of human sacrifices. Cannibalism is practised by some tribes.

The BANTU, who occupy practically the whole of Africa south of the Equator, and also extend north of it, are apparently a mixture of the true negro with Hamitic peoples (see below). In colour they are some shade of brown, often chocolate, and their hair is woolly. The stature is medium. Amongst the best-known groups or tribes are the Bechuanas, Basutos, Mashonas, and Zulus (Ama-Zulu) of South Africa; whilst in Central and Eastern Africa are the Baganda, and many others. The Bantu are much more advanced in many respects than the true negroes. They are chiefly cattle-rearers, but they also practise agriculture. They are warlike, and their social organization lends itself to the development of efficient armies. The assegai, a short spear with an iron point or blade, and the knobkerrie, a knobbed throwing-club, are characteristic weapons.

Before leaving the subject of the natives of Africa it is desirable to refer briefly to the group to which the term HAMITIC is applied. The WESTERN HAMITES (Berbers, Kabyles) of North Africa are probably related to the Mediterranean race of Europe (see p. 205); but the EASTERN HAMITES or ETHIOPIANS, including the Gallas, Somalis, and perhaps the ancient and modern Egyptians, are apparently an admixture of Negro and Semite (see p. 202). The Ethiopians present various shades of brown in their skin colour, and the hair is frizzly. The face is elongated, and the jaws are not protruding. The nose is prominent and thin, and the lips are not everted. In stature they are medium or tall. In all but skin colour they are easily distinguishable from the negro, their features often having quite a European cast.

OCEANIC NEGROES.—The negroid peoples—MELANESIANS—of the Western Pacific are found chiefly in New Guinea, the Bismarck Archipelago, Solomon Islands, New Hebrides, Fiji Islands, and New Caledonia. The skin colour is usually chocolate brown. In many instances they present evidences of admixture with the stock from which the Polynesians were derived (Proto-Polynesians), but amongst the Papuans of New Guinea especially are found the woolly hair, protruding jaws, and broad nose of the true negroid type. In most instances the Melanesians are long-headed, though brachycephaly occurs. Before the coming of the white man the Melanesians were, like the other races of Oceania, in their age of polished stone. This material was used especially for axe- and adze-heads, and shell was sometimes employed in the same way. Bone, teeth, and wood were used for cutting and piercing implements, such as

RACES OF MANKIND—II

1, Kalmuk (Northern Mongol).
2, Turk (Turko-Tatar).
3, Lapp (Mongoloid).
4, Andaman Islander (Negrito).
5, Sikh (Indo-Aryan).
6, Javanese (Oceanic Mongol).
7, Vedda (Pre-Dravidian).
8, Chinese (Southern Mongol).
9, Eskimo.
10, Carib (Southern American).
11, North American Indian.

4, 5

6

7

8

9

10

11

RACES OF MANKIND—II

knives, spears, and arrows. The TASMANIANS, who have now entirely disappeared, were in a still lower stage of culture, since they had not even got so far as to attach their stone implements to handles. The implements themselves were never ground and polished, and they are little better than the "eoliths" of Europe.

Pottery-making is practised in a few parts of Melanesia, but the art of spinning is unknown. The plaiting of strips of leaves and stems into mats, baskets, &c., and in one case the weaving of grass cloth, are amongst the industries carried on. Bark cloth is made, especially in the Fiji Islands. Simple agriculture is generally practised. In the decoration of implements, utensils, canoes, and other objects by means of carving or painting, the Melanesians manifest a marked degree of artistic skill. In disposition they are noisy, affectionate, and demonstrative, thus resembling the African negroes.

That there is a close relationship between the African and the Oceanic negroes can scarcely be called in question. The significance which lies in the distribution of both negritic and negroid peoples over two regions now widely separated by the Indian Ocean has already been referred to.

CHAPTER VIII

THE RACES OF MAN—(*Continued*)

AUSTRALIANS.—The Australian aborigines are a people of peculiar interest, and although they present several low characters, they cannot be regarded as being nearly related to the Oceanic negroes. They are fairly uniform in type, and it appears probable that they are in the main of the same race as some of the aboriginal peoples of India (the Pre-Dravidians), with perhaps some negroid admixture. In colour the Australians are dark brown, with curly hair. They are long-headed, and have protruding jaws and broad noses. In culture they are very backward, and live by hunting and collecting, no agriculture being practised. They have no domesticated animals except the dingo, perhaps brought by them into the country, which has no indigenous domesticable mammals. They rarely wear clothing, and have no permanent dwellings, though wood shelters and temporary huts are built. Spears and spear-throwers, short clubs, boomerangs, and wooden shields are their chief weapons, the bow and arrow being unknown. Wood, stone, bone, and shell are the principal materials they make use of for implements. Pottery-making and weaving are unknown, though they use a spindle in the making of string, especially from human hair. Much of the backwardness of the Australians is due to the nature of the country and its fauna and flora, but their isolation from other races has also been an obstacle to progress.

POLYNESIANS.—Widely distributed over the East Indian Archipelago

(occurring also in Northern India) and the Pacific are peoples whose main ingredient is the Indonesian race, although in Borneo, for example, there has been very intimate fusion with the stock from which the Malays were derived (Proto-Malays). The Polynesians, to whom we must confine our attention, are probably Indonesians, also modified by crossings with Proto-Malays, and to a less extent with Melanesians. By some ethnologists, however, they are regarded as a branch of the so-called "Caucasian" stock. In Hawaii, Samoa, New Zealand, and other islands of the Pacific, the Polynesians developed a considerable degree of culture, though they were in their age of polished stone when civilized man first arrived. In their tall stature, their oval face, high forehead, well-developed nose, light-brown complexion, and long curvy or wavy hair they differ widely from the Melanesians, and in individual cases they might well be taken for Europeans. They practise agriculture, but in the absence of indigenous mammals no domestication of any importance was possible. Their chief foods are vegetables and fish, though occasionally cannibalism was practised. In the making of bark-cloth they are very skilful, but spinning, weaving, and pottery-making were unknown. As navigators they had few equals, their voyages and migrations taking place over thousands of miles of ocean in canoes of simple construction. Their style of art is extremely characteristic, especially in wood-carving, by which means they decorate weapons, tools, and other objects. In disposition they are cheerful, dignified, and intelligent, though their sexual morality is not of the best. Women have a high position, however, and are not called upon to do the drudgery so often inflicted upon them even in civilized communities.

RACES OF AMERICA.—The aborigines of America are often regarded as a homogeneous race, sprung from a stock from which the Mongoloid peoples have also been derived. The theory is, however, inadequate to explain the differences in physical type that occur. They are sometimes divided into three groups: the Patagonians, Central Americans, and Northern Americans, as distinguished from the Southern Americans, and the ESKIMO of the Arctic Regions, the latter presenting many characteristic features.

The Eskimo are in many respects the most interesting group, especially with regard to the ingenious hunting weapons, such as the harpoon, which they have invented. They are short in stature, of yellowish complexion, with straight, black hair. In the eastern group they are very dolichocephalic, but the face is broad—an unusual combination. They are a littoral people, and live principally on seals, whales, and other sea mammals, but reindeer and other land animals are hunted. They never fight amongst themselves, and their only law is the power of custom.

AMERICAN INDIANS.—The American Indians in general have long, black, lank hair, complexion yellowish to coppery or rarely very dark brown, large straight or aquiline nose, and a stature above the average. In head form they range from brachycephalic to mesaticephalic. In degrees of culture there is also very great variety, from the savages of the South American forest or the miserable Tierra del Fuegians, to

the intelligent hunting and horticultural tribes of the North. In the civilizations of Mexico and Peru, moreover, the race showed itself capable of making great strides in culture.

MONGOLOIDS.—The peoples to which the term Mongoloid is often applied are chiefly straight-haired, brachycephalic races with yellowish complexion. It is by no means certain, however, that they form one stock, and the only invariable character is the straightness of the hair. If we exclude the American Indians, whose Mongolian affinities are doubtful, the Mongoloid peoples are chiefly found in Asia, where they constitute the bulk of the population, especially to the north and east of the Himalayas.

The Mongols proper include northern and southern groups. The KALMUKS are Northern Mongols in which the Mongolian characters are typically displayed: black straight hair, yellowish complexion, medium stature, round head (brachycephalic, under 83), prominent cheek bones, flattened nose, and eyes with an opening which appears oblique owing to folding of the upper lid. The Japanese, Manchus, Tunguses, and Chukchi are other Northern Mongols. Southern Mongols are the Tibetans, Chinese, Siamese, Burmans, and others, the Malays being usually called Oceanic Mongols.

The LAPPS of Northern Europe are in most respects characteristically Mongoloid, whereas the Finns, Bulgars, and Magyars have become more highly modified.

Of the TURKO-TATARS of Asia and Eastern Europe the Turks are politically the most important. They are moderately tall, brachycephalic, with long oval face, straight nose, yellowish-white complexion, and eyes which are non-Mongoloid.

In ability and enterprise many of these Mongoloid peoples have shown themselves to be of high capacity. The antiquity of Chinese civilization, and the recent remarkable advance of Japan, are evidences of the powers of the race. The Accadians who founded the Babylonian civilization are also believed to have been a Mongoloid people.

INDIAN RACES.—The population of India comprises so many races that only the merest outline can be given here. In most instances much crossing has taken place, and it is certain that none of the peoples are even approximately pure. The aboriginal inhabitants appear to have belonged to races that are usually called Pre-Dravidian and Dravidian. These are found over the whole of South India, from the Ganges to Ceylon. The PRE-DRAVIDIANS, from a migratory offshoot of which stock the Australians were probably derived, are best represented by the VEDDAHS of Ceylon, and the PANIYANS of Malabar. The Veddahs are apparently the most primitive, and they are characterized by a brown skin, long black wavy hair, prominent brow ridges, broad face, rather broad nose and small skull (cephalic index 70.5). They are very shy, and are greatly afraid of strangers; they live in caves or simple huts in isolated families, and have no chiefs. The DRAVIDIANS, which include the Bhils, Gonds, Kondhs, Sontals, Telegu, Tamils, Kotas, Todas, and others, are short in stature and of dark complexion; the nose is broad. In most cases they are

hunters or collectors, though many have become agriculturists, and others have even taken to commerce.

The several races that have invaded India at different periods have in most cases intermarried with the Dravidian peoples, though some have remained in a purer state than others. Amongst the representatives of the intruding races may be mentioned the INDO-ARYANS, such as the Rajputs and Jats, tall in stature, with fair complexion, long head, and narrow prominent nose; the Turko-Iranians, such as the Balooch and Afghans, differing from the Indo-Aryans in their broad head and very long, prominent, moderately narrow nose; and the MONGOLOIDS OF THE HIMALAYAS, Nepal, Assam, and Burma, with short stature, yellowish dark complexion, broad head and flat face, and often oblique eyelids. More mixed races are the SCYTHO-DRAVIDIANS, such as the Maratha-Brahmans, with broad heads and moderately fine nose; and the MONGOLO-DRAVIDIANS, such as the Bengal-Brahmans, with broad head and medium nose.

EUROPEAN RACES.—By far the greater part of Europe is occupied by races to which the term CAUCASIAN is often applied. The three main races of Europe will be considered in the following section, but mention may be made here of other peoples who are often included amongst the Caucasians. These are the Semites and the Armenians.

The SEMITES, with jet-black hair, tawny-white complexion, and fine regular features, are widely distributed over Western Asia and Northern Africa, the Arabs of Southern Arabia being the best modern representatives of the group. The Phœnicians, Israelites, and Assyrians were Semitic peoples. The Jews are a mixed race, and their characteristic nose is not Semitic but probably Assyrian. The Armenians are a peculiar people, with tawny white skin, broad head, and aquiline nose with depressed tip.

Amongst the so-called Caucasians are peoples widely spread over Europe, Persia, and India, whose languages are of common origin, and who are sometimes spoken of as belonging to one race, the ARYAN. These peoples include amongst others the three chief races of Europe (Northern, Central, and Mediterranean), the Iranians, and the Indo-Aryans. That all who speak these languages are in reality of one race is not now accepted, but in view of the importance that the "Aryan question" formerly had, it is desirable to consider what meaning can now be attached to the term Aryan. Even those with only a slight knowledge of such languages as French, Italian, and Spanish are in a position to test the statement that they are related to each other. They are, in fact, modifications of the language of the Romans, changed in grammar and syntax, altered and enlarged in vocabulary, but still recognizably based upon the Latin tongue. By comparison of such languages as Dutch, English, and German, these are also seen to be related to each other, and that much more closely than they are related to French, Italian, or Spanish. Most of the languages of Europe and several of those of Asia can be classified to form a smaller number of groups, and within these groups the individual languages are closely allied to each

other; not only so, but there is a more remote relationship between the several groups.

The principal groups or branches with their more familiar members are the following:—

Branch.	Languages.
Indic	Sanskrit { Hindu. Bengali.
Iranic	Afghan. Persian.
Armenic	Armenian. Ossetian.
Hellenic	Albanian. Ionian. Attic.
Italic	Umbrian. Latin { Italian. French. Spanish. Portuguese.
Keltic	Irish, Gaelic, Manx. Welsh, Cornish, Low Breton.
Slavic	Russian. Polish. Bulgarian.
Teutonic	Gothic. Dutch. Anglo-Saxon. English. Icelandic. Norwegian. German.

That there is any relationship between, say, Russian in the Slavic branch, Welsh in the Keltic, and English in the Teutonic would appear at first sight highly improbable, but the studies of philologists have shown conclusively that not only is this the case, but that all the languages in the above list (and many others) have been derived by gradual change from one original language, which has developed along many lines. A complete knowledge of the subject would enable us not only to reconstruct this ancestral language, but to show how it became modified and extended in the speech of the many races who inherited or adopted languages derived from it. To this hypothetical language, now long extinct, the term Aryan has been applied; and Indo-European or Indo-Germanic is sometimes used in the same sense.

The discovery of the relationships between the Aryan languages has been of immense importance in Ethnology, but there was formerly a tendency to exaggerate its significance. It was supposed that the people who spoke the original Aryan tongue sent off migratory swarms, which occupied all the regions where Aryan languages are now spoken, to the practical exclusion of all other races. It was therefore concluded that

all peoples now speaking Aryan languages, however different they might be in physical type, are of common origin. Language was, for the purposes of this theory, regarded as a criterion of race, and it is upon this point that a fierce controversy formerly raged. The rejection of the theory, other evidence being opposed to it, is justified by the fact that in the history of man, even within the last few hundreds of years, there are many examples of races adopting languages other than their own. History abounds with instances of colonizing and conquering peoples imposing their language upon others, and, conversely, of the absorption of colonizers or invaders by the occupants of the country they have overrun. In our own country we have examples of both these processes. The Anglo-Saxons conquered the greater part of England and fused with the Britons, who spoke a Keltic language. The latter gave place to Anglo-Saxon, except in outlying regions such as Cornwall and Strathclyde. When, on the other hand, the Normans conquered Anglo-Saxon England, the native language remained essentially unaltered, though it was modified and enriched by the influence of the Norman-French. Aryan languages are spoken both in Europe and in Asia by peoples differing considerably in physical type—long heads and short heads, fair and dark, tall and short. The languages have been gradually diffused by migrations, conquests, fusions, and as they have spread they have become modified until the interrelationships are in many cases only recognizable by the skilled philologist. They have been adopted by or forced upon a number of distinct races, and Aryan speech is not a sufficient guarantee of Aryan blood.

Many views are held as to what existing peoples may be regarded as representing most nearly the original Aryan-speaking race, and also as to the original home of this race. These views need not detain us here, but it is interesting to consider briefly what stage of culture the ancestral stock had probably reached before their migrations began. Word-roots have been identified as common to so many of the Aryan languages that it is a legitimate inference that the primitive Aryans were familiar with the objects to which they apply. They appear to have been a pastoral people, possessing domesticated animals such as the dog, sheep, goat, and ox. They had little knowledge of agriculture, but they made pottery, and had begun to weave garments of flax and wool. They dwelt in huts roofed with turf or with branches of trees. Their implements were made largely of stone, and on the whole their stage of culture probably resembled that which is regarded as characteristic of the Neolithic Age in Western Europe. It is probable that during this period they began to spread from their original home, which appears to have been situated in an open region, far away from the sea, where severe winters and hot summers prevailed. It may well have been somewhere in the great steppe region which extends from east to west over central Europe and Asia, and the race was probably widely distributed over its native land.

CHAPTER IX

THE RACES OF EUROPE—THE RACES OF BRITAIN

THE RACES OF EUROPE.—The bulk of the present population of Europe is made up of three main races, which have intermingled in various degree in different parts of the area (see the Plate EUROPEAN TYPES). It is still easy to detect the broad distinction between the populations of Northern, Central, and Southern Europe respectively. We are never surprised to hear, for example, that a tall, fair man comes from the north and a short, dark man from the south.

The NORTHERN RACE, variously called also Germanic, Teutonic, Nordic, is characterized in typical cases by long head and face, light wavy hair and blue eyes, long narrow nose, a florid skin, and tall stature. Scandinavia is the present home of the most typical examples of this race, though the type is well marked in Holland, Russia, North Germany, the British Isles, and elsewhere.

The CENTRAL RACE, called also Celtic, Alpine, is characterized by a short head and broad face, large thick nose, light-brown wavy hair, grey eyes, sallow skin, and medium stature. It is now found in its purest state in Switzerland, Russia, South Germany, North Italy, and parts of France. Owing to its geographical position it has become greatly modified in most regions by intermixture with the races to north and south of it. Some ethnologists are of opinion that this race is proving itself to be better adapted to modern industrial conditions than the Northern race.

The MEDITERRANEAN RACE, called also Iberian, Afro-European, is distinguished by a long head and face, broad nose, brown or black wavy hair, dark eyes and skin, low stature, and slender build. It is found chiefly in Spain, Greece, the peninsula of Italy, the south of France, and the British Isles (and also in North Africa).

In several parts there are found groups of people of Mongoloid type, such as the MAGYARS of Hungary, the LAPPS and FINNS of Northern Europe, and the TURKS of Eastern Europe. These represent invasions or infiltrations, as the case may be, of Asiatic peoples.

RACES OF BRITAIN.—The three main races of Europe are represented in the British Isles. It is possible that Palæolithic man, who is not included in these groups, may have transmitted some of his characters, but the racial history of Europe and the British Isles from the anthropological standpoint may be taken to begin with the Neolithic Age. There appears to have been more than one race in Europe during the Palæolithic Age, the earlier types presenting low characters, such as prominent brow ridges and a retreating forehead (*Homo neanderthalensis*). At a later period the type was distinctly higher, but we do not know what part, if any, Palæolithic men played in the composition of the Neolithic races.

In Great Britain, as in South Europe, the men of the Neolithic Age appear to have been of the Mediterranean Race. Where this race first developed is not known, but in very early times it was found in North Africa, and the civilization of Egypt is believed by some to have been founded by this race.

During the early part of the Neolithic Age the Central Race is believed by some to have entered Europe from the east, and it is possible that it was a branch of an Asiatic Mongoloid stock, though there is now a strong tendency to regard it as of indigenous origin in Europe. The pure Central Race never reached England, which was, however, invaded by a tall, broad-headed race, probably representing a fusion between peoples of the Northern and Central Races. The knowledge of bronze seems to have been introduced into the British Isles by these people, and it may be that the use of iron was brought in by later waves of immigrants of the same mixed stock.

The Roman invasion did not greatly affect the composition of the British race, but the Anglo-Saxon conquest added considerably to the northern element in the mixture. The Danish invasions and the Norman Conquest added similar elements, though no doubt in an impure state.

Taken as a whole, the present population of the British Isles shows considerable uniformity in certain characters, such as the average head form (mesaticephalic), but in many parts a predominance of one or other of the three chief races may still be traced. The short, dark people of Wales, Ireland, Cornwall, Inverness, Argyll, the Fens, and of a region to the north of London, represent the Mediterranean Race in its least-modified form. The Northern Race is represented in its greatest purity in the north and east of Britain, and traces of the Central Race are found in Fife, Aberdeen, the islands to the north of Scotland, and on the north-west coast of Ireland.

Such conclusions as the above are only arrived at by a careful study of the stable populations of the different regions, and they only represent the physical type of the people in a general way. All the three races (except, perhaps, the Central) may be traced in practically all parts of the country.

The problem of the KELTIC RACE and the Keltic language is somewhat similar to that of the Aryans, though on a smaller scale. It has long been the custom to regard the Keltic-speaking peoples of Wales, Scotland, Ireland, and Brittany as being racially allied. This leads, however, to the assertion that the short, dark people of South Wales are of the same race as tall, fair people in Scotland, whereas it is probable that the distinctive characters of the former are derived from the Mediterranean Race and those of the latter from the Northern Race. The Keltic language may have been the speech of either the Northern Race or the Central Race, if the theory is correct that it was a mixture of these two stocks that brought the type of language into Britain. In any case the forefathers of the present-day "Kelts" of Wales, Ireland, and Scotland were not all of the same origin. The word Kelt has, in fact, been so misused that it has

EUROPEAN TYPES

1, Englishman (old British type).

2, Englishman (old British, broad-headed, probably Bronze Age type).

3, Irishman (probably Mediterranean and Northern blend).

4, Scandinavian (Northern race).

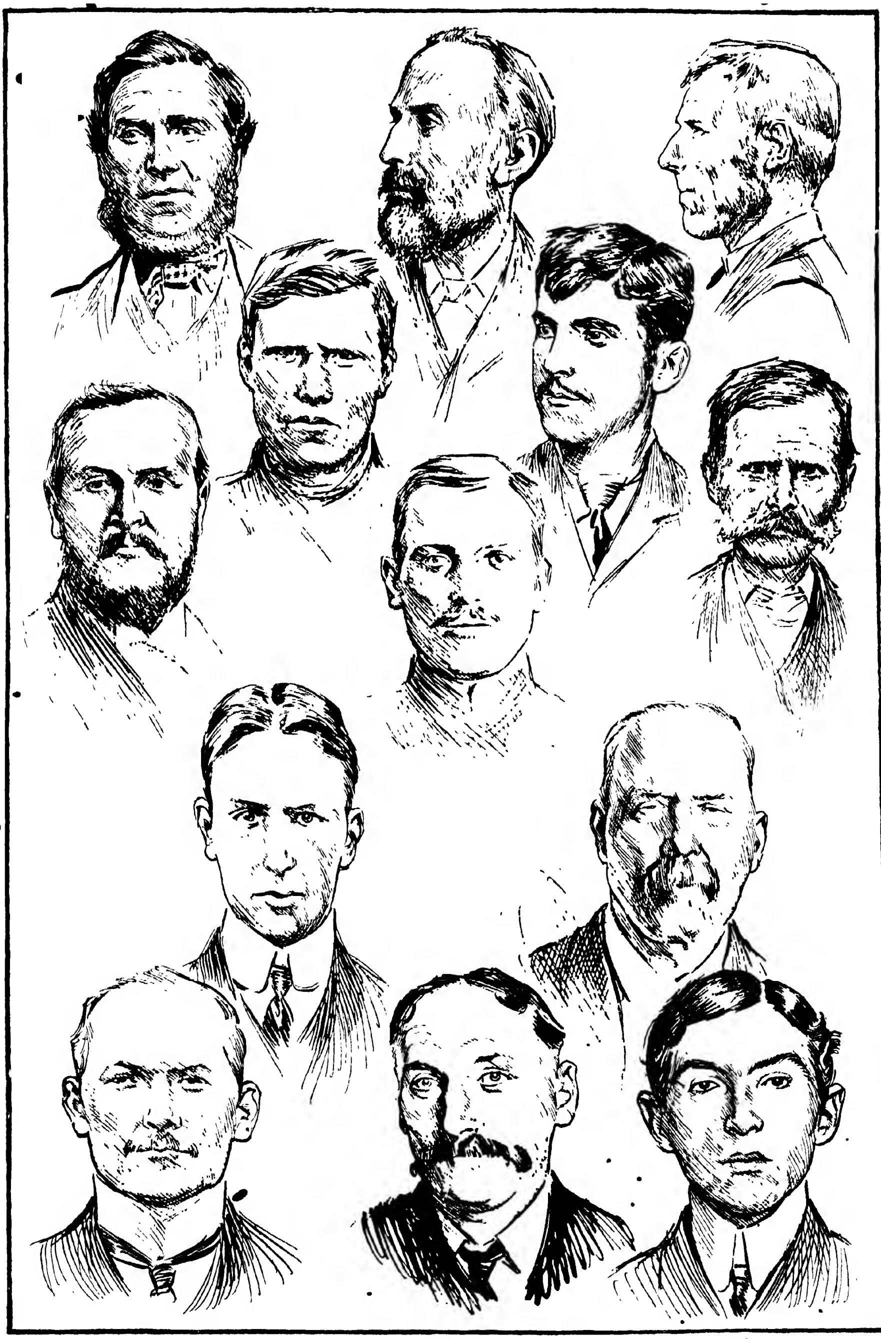
5, Spaniard (Mediterranean race).

6, Frenchman (Central race).

7, South German (probably Northern and Central blend).

8, Magyar (Mongolian).

9–13, Welshmen, showing considerable variety in form of head and face, complexion, &c. 9 and 10 are long-headed, 11 and 12 are medium-headed, and 13 is broad-headed. On the basis of language all would be classed as "Kelts".



11 12 13

EUROPEAN TYPES

now no ethnical significance. The average Englishman has probably as much, or as little, Keltic blood as the average Welshman, Irishman, or Scotsman. A modern "Kelt" is more likely to be of either Mediterranean or Northern blood than of any other, and these are the two chief components of the Englishman. In any case, however, the inhabitants of the British Isles have little cause to boast of racial purity.

LIST OF WORKS RECOMMENDED FOR FURTHER STUDY.

Name.	Author.	Publisher.
*THE DESCENT OF MAN ...	Charles Darwin ...	John Murray.
*MAN'S PLACE IN NATURE ...	T. H. Huxley	Macmillan & Co.
*ANTHROPOLOGY, AN INTRODUCTION TO THE STUDY OF MAN AND CIVILIZATION	E. B. Tylor	Macmillan & Co.
*THE STUDY OF MAN ...	A. C. Haddon ...	John Murray.
*THE ORIGINS OF INVENTION	O. T. Mason	Walter Scott.
THE EVOLUTION OF CULTURE AND OTHER ESSAYS ...	A. H. Lane-Fox (afterwards Fox Pitt Rivers)	Clarendon Press.
*THE EVOLUTION OF DECORATIVE ART	H. Balfour	Rivington.
EVOLUTION IN ART	A. C. Haddon	Walter Scott.
THE ALPHABET	J. Taylor	Edward Arnold.
EARLY MAN IN BRITAIN ...	W. Boyd Dawkins ...	Macmillan & Co.
THE ORIGIN OF CIVILIZATION	Sir John Lubbock (Baron Avebury)	Longmans.
PRIMITIVE CULTURE	E. B. Tylor	John Murray.
THE ANCIENT STONE IMPLEMENTS OF GREAT BRITAIN	Sir John Evans ...	Longmans.
*MAN, THE PRIMÆVAL SAVAGE	W. G. Smith	Stanford.
*REMAINS OF THE PREHISTORIC AGE IN ENGLAND	B. C. A. Windle ...	Methuen.
*ETHNOLOGY	A. H. Keane	Cambridge Univ. Press.
MAN, PAST AND PRESENT ...	"	"
*THE RACES OF MAN ...	A. C. Haddon ...	Milner & Co.
THE RACES OF EUROPE ...	W. Z. Ripley	Kegan, Paul, & Co.
THE RACES OF BRITAIN ...	J. Beddoe	Arrowsmith.

(Those marked with an asterisk are the more suitable for the general reader.)